INCIDENTAL HARASSMENT AUTHORIZATION REQUEST

THE AGULHAS RETURN CURRENT RESEARCH PROJECT (ARC12): A PHYSICAL OCEANOGRAPHIC SURVEY BY THE U.S. NAVAL RESEARCH LABORATORY, 23 JANUARY TO 8 FEBRUARY 2012

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Office of Protected Resources
National Marine Fisheries Service
National Oceanographic and Atmospheric Administration

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EXECUTIVE SUMMARY

The Naval Research Laboratory (NRL) Marine Geosciences and Oceanography Divisions plan a joint mission to conduct physical oceanographic research in the southwest Indian Ocean, approximately 150 to 600 nautical miles (278 km to 1100 km) off the coast of South Africa, during the period of 23 January to 8 February 2012. Some minor deviation in these dates is possible due to logistics and weather. Research activities will encompass a total of 17 days with the acoustic sources operating up to 24 hours per day. Research will focus on quantifying the physical processes of ocean mixing at the frontal region between the Agulhas Return and Antarctic Circumpolar Currents in waters ranging in depth from approximately 1,000 to 5,200 meters. Research will investigate diapycnal mixing to better understand the exchange of waters at major ocean frontal systems; which is fundamental process in global ocean circulation, and key parameter in modeling the relationship between global ocean circulation and climate change.

The research project will use a high resolution seismic oceanographic (SO) technique that employs a towed array of two low-energy 105 in^3 generator injector air guns (GI-guns), which allows detailed imaging of the water column fine structure. The SO survey will be conducted concurrent with other physico-chemical studies enabling a comprehensive, detailed investigation of ocean mixing dynamics at 10-meter horizontal resolution. Additional acoustic sources include a multibeam echosounder, sub-bottom profiler, onboard Acoustic Doppler Current Profiler (ADCP), moored ADCP, and lowered ADCP.

An Overseas Environmental Assessment (OEA) was prepared by the Department of the Navy (DoN) in accordance with Executive Order (EO) 12114, Department of Defense (DoD) regulations found at 32 Code of Federal Regulations (CFR) Part 187, DoD Directive 6050.7, and Chief of Naval Operations (CNO) Instruction (OPNAVINST) 5090.1C, Appendix E. Based upon the analysis presented in the OEA it was determined the proposed research activities:

- will not significantly harm the environment;
- will result in the exposure of Federally listed species to acoustic sources requiring consultation with the National Marine Fisheries Service (NMFS) under Section 7 of the U.S. Endangered Species Act (U.S. ESA);
- will result in the exposure of marine mammals to acoustic sources that will require NMFS authorization for incidental harassment under the U.S. Marine Mammal Protection Act (U.S. MMPA).

Because of these determinations, NRL is requesting authorization for the Level B incidental harassment of 2413 marine mammals. This total includes 62 endangered species; 29 fin, 1 humpback, 11 sei, 1 southern right, and 20 sperm whales. The number of marine mammals potentially incidentally harassed is less than 0.2% of the population for which global and regional population density estimates are known.

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LIST OF ACRONYMS

AC	Agulhas Current
ACC	Antarctic Circumpolar Current
ADCP	Acoustic Doppler Current Profiler
ARC	Agulhas Return Current
ASCLME	Agulhas and Somali Current Large Marine Ecosystems
BPA	Benthic Protected Area
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CTD	conductivity-temperature-depth
DCS	decompression sickness
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
ESA	(U.S.) Endangered Species Act
ETP	equatorial tropical Pacific
EZ	Exclusion Zone
FAO	Food and Agriculture Organization
GI	Generator-Injector
IHA	Incidental Harassment Authorization (under the U.S. MMPA)
in	inch
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
IWC/SOWER	IWC's Southern Ocean Whale and Ecosystem Research Program
kHz	kilohertz
km	kilometer
kt	knot
kW	Kilowatt
L-ADCP	Lowered ADCP
L-DEO	Lamont-Doherty Earth Observatory
LR-ADCP	Long-Range ADCP
m	meter
LME	Large Marine Ecosystem
MAI	Marine Acoustics Incorporated
MBES	Multibeam echosounder
min	minute
MMO	Marine Mammal Observer
MMPA	(U.S.) Marine Mammal Protection Act
ms	millisecond
NAVFAC	Naval Facilities Engineering Command
NEPA	(U.S.) National Environmental Policy Act
NMFS	(U.S.) National Marine Fisheries Service
NMSDD	Navy Marine Species Density Database
NOAA	National Oceanographic and Atmospheric Administration
NRC	National Research Council
NRL	Naval Research Laboratory
NSF	National Science Foundation
Nm	nautical mile
OBIS	Ocean Biogeographic Information System
OEA	Overseas Environmental Assessment
PAM	Passive Acoustic Monitoring
PTS	Permanent Threshold Shift
pk/p	peak

rms	root mean square
s	second
SA	South Africa
SBP	Sub-bottom Profiler
SEL	Sound Exposure Level
SIODFA	Southern Indian Ocean Deepwater Fishers' Association
SL	source level
SMRUL	Sea Mammal Research Unit Limited
SO	seismic oceanography
SPL	sound pressure level
TEU	twenty-foot equivalent unit
TTS	Temporary Threshold Shift
TRDI	Teledyne RD Instruments
USGS	U.S. Geological Survey
VMP	Vertical Microstructure Profiler
XBT	Expendable bathythermograph
XCTD	Expendable CTD

1.0 DESCRIPTION OF RESEARCH ACTIVITIES

1.1 Project Overview

The Naval Research Laboratory (NRL) Marine Geosciences and Oceanography Divisions plan a joint mission to conduct physical oceanographic studies of the frontal region between the Agulhas Return Current (ARC) and Antarctic Circumpolar Currents (ACC) off the coast of South Africa from 23 January to 8 February, 2012. Some minor deviation in these dates is possible due to logistics and weather. The project is a collaborative effort between NRL Chief Scientists, the United Nations Development Program Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project, the University of Cape Town, South Africa, and the University of Kiel, Germany.

Better understanding the mixing of ocean waters with different physical and chemical characteristics, and the influence of ocean mixing on climate, is not only important from the perspective of basic scientific research, but also essential to predicting the marine environment in which the Navy Fleet operates. The purpose of the proposed action is to study the mixing of ocean waters with different physical and chemical characteristics. Ocean mixing is a fundamental process in global ocean circulation, and key parameter in modeling the relationship between global ocean circulation and climate change. Specifically, the goal of the proposed action is to better understand diapycnal mixing, a fundamental process involved in global ocean circulation and the uptake and transport of heat and carbon dioxide (CO_2). It is a key mechanism governing the exchange of waters at major ocean fronts, particularly regions of sub-polar and sub-tropical frontal systems, such as the North Atlantic Current and Labrador Current, the Kuroshio and Oyashio Currents, and the ARC and ACC. Further elucidating the processes of ocean mixing is fundamental to improved modeling of global ocean circulation, heat and energy transport, and bettering our understanding of the relationship between global ocean circulation and localized changes in climate and marine habitat (Brown et al. 2010). Although diapycnal mixing occurs at several ocean fronts around the world, the region of the ARC/ACC off the coast of South Africa is an optimal site because: (1) it is a major ocean front in which significant volumes of waters and energy are exchanged; and (2) it has considerable eddy activity. The ACC conjoins the Atlantic, Pacific, and Indian Ocean basins, and serves as a principal pathway for the exchange of waters, and transport of heat, nutrients, and salts, between these ocean basins.

Current data on variables governing ocean mixing and circulation lack sufficient resolution to accurately describe global ocean circulation. For example: extant ocean temperature, salinity, and current data lack sufficient detail to accurately model and describe variability in Meridional Overturning Circulation (MOC), which is driven by temperature, salinity, wind, and tidal forcing. Since rapid changes in MOC could have implications for regional changes in climate, the capability to better quantify variables such as the Meridional Overturning (MO) stream-function, heat storage, and meridional heat transport is needed. As such, research goals are to obtain high resolution imaging of ocean mixing dynamics at the ARC/ACC front through the use of a technique termed seismic oceanography (SO). For this project, high resolution SO profiling of the water column will be accomplished using a towed array of two low-energy 105 in^3 Generator-Injector air guns (GI-guns).

In the past, SO has been used to image the fine-scale and mesoscale structure of the water column at major ocean fronts and to quantify thermohaline (that part of the large-scale ocean circulation driven by variations in temperature and salinity) circulation. However, interpretation and extrapolation of data from past SO studies has been limited by the lack of associated physical oceanographic measurements necessary for a more comprehensive dataset. SO profiling will be conducted in tandem with other physico-chemical studies enabling a comprehensive, detailed investigation of ocean mixing dynamics at 10-meter horizontal resolution. Information and data derived from the study will provide the capability to better quantify diapycnal mixing dynamics, improve the ability to model MOC, and better understand the integrated relationships between the mechanisms of ocean mixing, global ocean circulation, and climate change.

1.2 Research Activities to be Conducted

As detailed under the purpose and need, studies will focus on the process of diapycnal mixing at the frontal system of the Agulhas Return Current (ARC) and Antarctic Circumpolar Current (ACC), off the coast of South Africa. The RV *Melville* will depart from Cape Town South Africa on 23 January 2012, and return to port in Cape Town approximately 8 February 2012. Some minor deviation in these dates is possible due to logistics and weather, with variation being no more than one week earlier, or two weeks later, than dates described. Research activities will be conducted for a total of 17 days over the region described. SO surveys will be conducted for 14 days in the area of the Agulhas Plateau, and acoustic Doppler current profiler (ADCP) mooring deployments and recoveries, other oceanographic sampling methods, as well as transit to and from the site of study, will comprise 3 days of research activities. The exact locations of the ARC/ACC frontal system will be determined on site due to the natural meander of the ARC and ACC. High-resolution conductivity-temperature-depth (CTD) measurements will be used to locate the ARC/ACC frontal system. Subsequently, lowered ADCPs (L-ADCP) will be deployed across and in the ARC along with temperature/salinity sensors to measure targeted endpoints. One to four moored ADCPs will be deployed on the northwestern flank of the Agulhas Plateau where the ARC/ACC front is expected to be phase locked (meaning the normal location of occurrence of the front). Turbulence and physico-chemical data will be obtained using CTD measurements, deployment of expendable bathythermographs (XBTs) and/or expendable CTDs (XCTD), Vertical Microstructure Profiler (VMP) surveys, and acquisition of hydrographic data via ADCP measurements. Once the ARC/ACC front is located SO surveys will be conducted using a towed array of two low-energy 105 in^3 GI-guns. SO profiling studies will encompass a total linear distance of ~2489 km, and be comprised of multiple transects across and along the ARC/ACC front. RV *Melville* operational speeds during the SO survey will be 4 to 6 knots (7 to 11 km/hr). When not conducting SO studies, the RV *Melville* will be operated at cruise speeds of ~11 knots (22 km/h), which will occur during transit to and from port to the site of study. After the SO profiling survey is completed, moored ADCPs will be recovered.

1.3 Location of Research Activities

The ARC/ACC frontal region is located within the coordinates 36°S to 43°S, and 19°E to 30°E, in the area of the Agulhas Plateau. The exact location of ARC/ACC front in January 2012 cannot be predetermined due to the natural meander of the Agulhas Current (AC), ARC, and ACC, and it follows, the ARC/ACC front. While the frontal system is expected to be phase locked (meaning the normal location of occurrence of the front) at approximately 36°S to 40°S, and 21°E to 27°E, models poorly simulate and predict the meander of the frontal system, and the estimated location of the front may not be accurate. The ARC/ACC frontal system may meander more than 100 km west, south, and east of the position where the front is expected to be localized (Figures 1.0 and 1.1), and would never be expected to meander farther north than 36°S due to northern boundary of the AC. Hence, due to the normal variability in the location of the ARC/ACC front, poor predictive value of extant mathematical models of the meander of the Agulhas Current (AC) and ARC, and unpredictable nature of weather conditions, determination of the exact location of research activities is not possible. However, it is known with a reasonable amount of certainty that ARC and ACC will be located within the boundaries of 36°S to 43°S, and 19°E to 30°E, and as such, research activities will occur within the region described by these coordinates. The total area of this region is ~207,500 Nm^2 (~713,000 km^2), which is the scale of the normal meander of the currents and frontal system of interest.

Due to the aforementioned reasons, and uncertainty in the exact location of front during January 2012, studies will take place ~150 to 600 nautical miles (278 km to 1100 km) due south of the South African coast. As such, the area described area comprises both waters of the global commons (high seas) and South African exclusive economic zone (EEZ). It is expected that the majority of studies will occur in waters of the global commons (high seas), with some potential for studies to be conducted in the South African EEZ. Waters in this region range from approximately 1000 m to 5200 m in depth. All studies will be conducted in deep water, with minimum depths of ~ 2000 m.

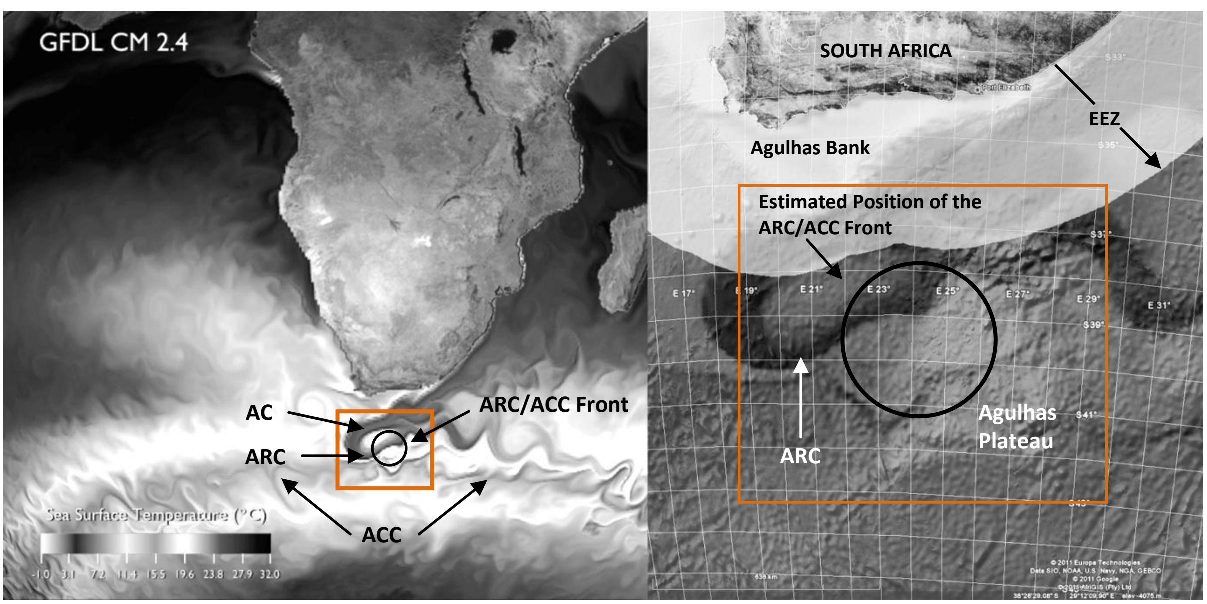

Figure 1.0 The Agulhas Return Current and Antarctic Circumpolar Current Front: The ARC and ACC frontal region is located within the coordinates 36°S to 43°S, and 19°E to 30°E, in the area of the Agulhas Plateau, indicated by the orange square. The region within the coordinates 36°S to 43°S, and 19°E to 30° describes the scale of the natural meander the ARC and ACC, and thereby, ARC/ACC front. The total area of this region is ~207,500 Nm^2 (~713,000 km2), and the ARC/ACC front is estimated to be phase-locked at the position

indicated by the black circle, roughly between 36°S to 40°S, and 21°E to 27°E. However, the frontal system may be located 100 km west, east, or south of this position, though within 36°S to 43°S, and 19°E to 30°E. Agulhas Current (AC), Agulhas Return Current (ARC), Antarctic Circumpolar Current (ACC), Exclusive Economic Zone (EEZ). Original image source (left): NOAA Geophysical Fluid Dynamics Laboratory (GFDL).

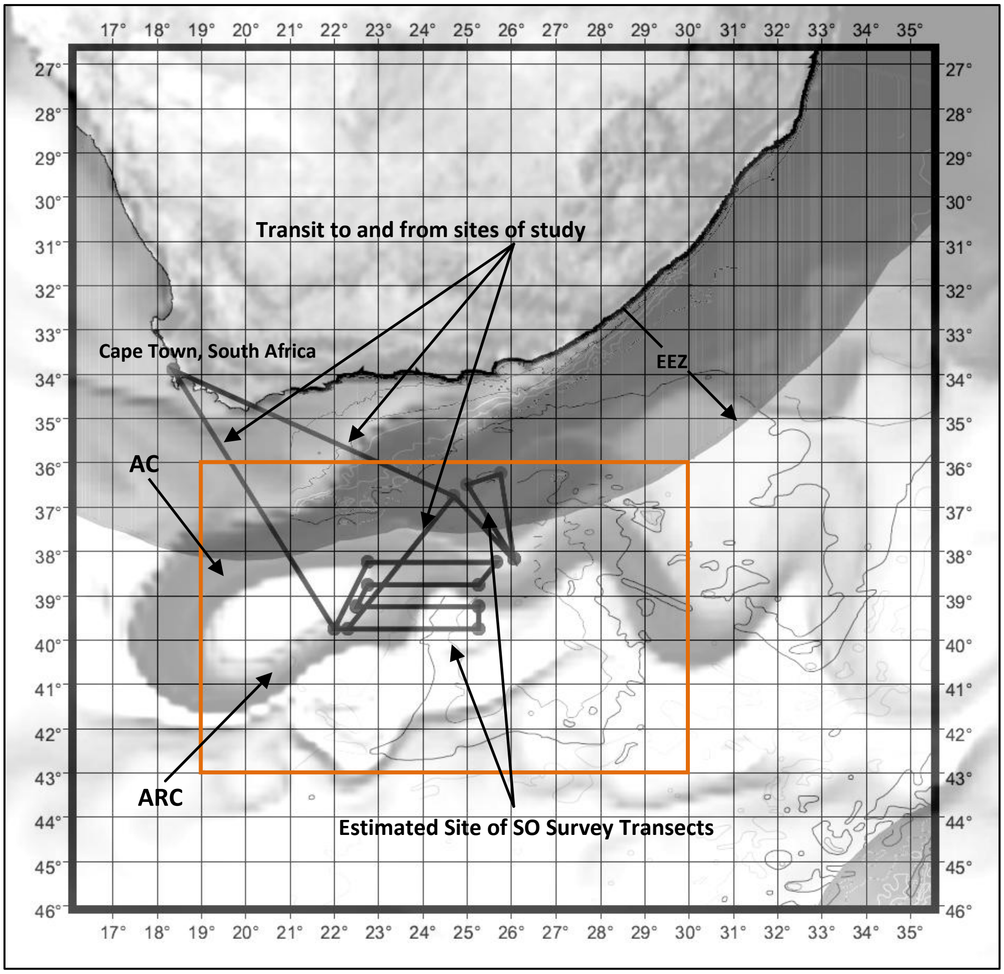

Figure 1.1 Area of Study and SO Transects: Studies will take place ~150 to 600 nautical miles (278 km to 1100 km) due south of the South African coast. SO profiling studies will encompass a total linear distance of ~2489 km, and be comprised of multiple transects across and along the ARC/ACC front. The course and location of the SO survey transects indicated are estimated and may not be exact, due to the natural meander of the AC, ARC, and ACC, and it follows, the ARC/ACC front. While the frontal system is expected to be phase locked (meaning the normal location of occurrence of the front) at approximately 36°S to 40°S, and 21°E to 27°E, mathematical models poorly simulate and predict the meander of the frontal system, and the estimated location of the front may not be accurate. It follows, while the SO survey will occur within the coordinates of 36°S to 43°S, and 19°E to 30°E (orange square), the precise location of the study area cannot be predetermined, and the frontal system, and site of study, will be located on site. Agulhas Current (AC), Agulhas Return Current (ARC), Exclusive Economic Zone (EEZ).

1.3.1 Acoustic Equipment

GI-gun Array

A Generator-Injector (GI) gun is a stainless steel cylinder charged with high-pressure air that, when instantaneously released into the water column, generates sound. Multiple chambers can be used to release different volumes of air microseconds apart to fine tune bubble expansion and sound characteristics. In this study, two GI-guns will be operated in harmonic mode (105in^3 in each of the generator and injector chambers) with a 1200 m long hydrophone streamer. GI-guns will be energized simultaneously at 2,000 psi every 17 s (~35 m). SO studies will be conducted 24 hours per day for 14 days (336 hrs). Sound pressure output levels for the GI-guns are 234 dB re 1 μPa.m (0-p), and 240 dB re 1 μPa.m (p-p).

Table 1.0 Acoustic Sources: GI-gun Array

Description	Frequency (Hz)	Source Level (dB re 1 μPa.m)	Shot-Repetition Rate	Discharge Volume	Tow Depth (m)
2-105 in^3 GI-guns	10-188	240 (p-p)	17 seconds	210 in^3	3 to 9

Ocean Surveyor ADCP

A hull mounted Teledyne RD Instruments Ocean Surveyor ADCP (TRDI OS ADCP) will be operated at 38 kHz with acoustic output pressure of 224 dB re 1 µP.m. The beamwidth is 30º off nadir and the acoustic pressure along each beam is estimated at 180 dB re 1 µP @ 114 meters.

Lowered ADCP

A lowered TRDI ADPC (L-ADCP) will be mounted on a rosette with a CTD. Output pressure is 216 dB re 1 μPa.m at 300 kHz, and beamwidth 30° off nadir.

Moored ADCP

Up to four of NRL's long range ADCPs (LR-ADCP) will be anchored on the seafloor using 400 kg of scrap iron (assemblage of 4 scrap locomotive wheels). LR-ADCPs will be moored to the seafloor at a ~3000 m such that they float at a depth of 500 meters below the sea surface. LR-ADCPs will be suspended from the iron anchorage assemblies by a single line comprised of ¾" nylon line and ½" wire rope. The LR-ADCPs and suspension line will be recovered at the close of the study via an acoustic release. The iron anchorage assembly will remain on the sea floor. The acoustic source frequency is 75 kHz, and output pressure level 200 dB re 1 µP.m at a rate of once per second. The beamwidth is 4° and directed vertically upward at 20°. The beamwidth is 4° and directed vertically upward at 20°. LR-ADCPs will be moored several kilometers apart, in the area of the ARC/ACC frontal system, with exact mooring locations to be determined onsite due to the natural meander of the currents and front. LR-ADCPs will be moored with acoustic releases from Teledyne RD Instruments (e.g., Model 865-A Deep Sea Acoustic Transponding Release, or a similar release system), which transmits in the frequency range of 7.0 to 15.0 kHz.

Multibeam Echosounder

The hull mounted Kongsberg EM 122 (MBES) operates at 10.5 to 13 kHz. Acoustic pulses generate a downward fan-shaped beam, 1° fore–aft and 150° athwartship. For deep-water operations each "ping" is comprised of eight (in water > 1,000 m; 3,280 ft) or four (< 1,000 m; 3,280 ft) successive acoustic transmissions 2 to 100 ms in duration. The maximum sound pressure output level is 242 dB re 1 μPa.m.

Sub-bottom Profiler

The hull mounted Knudsen 320B/R sub-bottom profiler (SBP) is dual frequency and operates at 3.5 and 12 kHz. The maximum power output of the SBP is 10 kW at 3.5 kHz and 2 kW at 12 kHz. The pulse length used during this study is 0.8 to 24 ms, relative to water depth and sediment characteristics. Pulse repetition rate is between 0.5 to 2 s in shallow water and up to 8 s in deep water (depth dependent). A common operational mode is broadcast of five pulses at 1 s intervals followed by a 5 s delay. Maximum acoustic output pressure at 3.5 kHz is 211 dB re 1μPa.m; however systems are typically operated at ~80% capacity. At 3.5 kHz the SBP emits a downward conical beam with a width of approximately 30°.

Table 1.1 Acoustic Sources: MBES, SBP, and ADCPs

Acoustic Source	Frequency (kHz)	Source Level (dB re 1 μPa.m)	Pulse Length (seconds)	Ping Rate (seconds)	Beamwidth/ Directionality
Kongsberg MBES	12	242	0.002- 0.1	1.5- 20	1° by 150° /Down-Vertical
Knudsen SBP	3.5	211	0.0008 - 0.024	0.5 - 8	30° / Down-Vertical
TRDI OS ADCP	38	224	0.02 - 3	0.2- 6	30°/Down-Variable
L-ADCP	300	216	0.01	1	30°/Variable
LR-ADCP	75	200	0.02	2	4°/Upward-Vertical 20°

1.3.2 Non-Acoustic Equipment

Vertical Microstructure Profiler

The VMP is a free-fall instrument that measures temperature, salinity, and velocity profiles with high vertical resolution (to 1 cm). The VMP will be recovered after each deployment.

Expendable Bathythermographs/CTDs

Up to 250 XBTs and/or XCTDs are expected to be deployed. XBTs/XCTDs are typically 15 inches in length by 3 inches in diameter, and composed primarily of a zinc alloy "nose", acrylonitrile-butadiene-styrene (ABS) plastic body, and copper wire. XBTs/XCTDs fall through the water column at ~ 6 m/s and will embed in the benthos. XBTs/XCTDs will not be recovered, and will remain on the sea floor at the conclusion of the study.

CTD

CTD metrics will be acquired via standard wire-line measurements. The instruments are cast and recovered, and will not be expended.

1.3.3 Sound Propagation Radii for the GI-gun Array

Lamont–Doherty Earth Observatory (L-DEO) developed a verified model that predicts impulsive sound pressure, field propagation and accurately describes acoustic propagation in marine waters of depths greater than 1000 m. These model-generated sound propagation radii are routinely used for determination of received sound levels generated by impulsive sound sources, and have been previously applied in calculating the total ensonified area for use of two low-energy 105 in^3 GI-guns. Modeled sound propagation radii of GI-gun sources that are the same or similar to the GI-guns used in this study, in water depths >1000 m, are given in Table 4.2. These modeled acoustic propagation distances were applied in EAs/IHAs for seismic surveys conducted in the Eastern Tropical Pacific (ETP) Ocean off of Central America (NMFS 2004), the Northern Gulf of Mexico (GOMex) (L-DEO 2003; NMFS 2007), and Arctic Ocean (NMFS 2006).

For the ETP one and three 105 in^3 GI-gun arrays were modeled, with a source output level of 241 dB re 1 µP.m (0-p) and 247 dB re 1 µP.m (p-p). For the GOMex survey GI-gun source output levels were (a) 237 dB re 1 µP.m (0-p) and 243 dB re 1 µP.m (p-p), and (b) 229 dB re 1 µPa.m (0-p) and 236 dB (p-p). L-DEO modeling of a single G-gun has also been applied to a seismic survey in the Arctic Ocean. The source level for the 210 in^3 G-gun was 246 dB re 1 µPa.m (0-p) and 253 dB re 1 µPa.m (p-p). Note: Because the G-gun generates more energy than a GI-gun of the same size, the distances for received sound levels may overestimate for the lower energy dual 105 in^3 GI-gun source used in the ARC12 research project. The GI-gun is comprised of two, independently fired air chambers (the generator, and the injector, respectively) to tune air bubble oscillation and minimize the amplitude of the acoustic pulse. G-guns, comprised of one chamber, generate a single, less refined, injection of air into the water, which produces more acoustic energy than that of the GI-gun.

Table 1.2 Modeled Sound Propagation Radii for Low-Energy Air-Gun Arrays for Depths > 1000 Meters

Air-gun Configuration	Water Depth (meters)	Tow-Depth (meters)	Received Sound Levels (dB re 1 µPa.rms) 190	180	170	160	Location
			Distance (meters)				
1 GI-gun 105 in^3	> 1000	2.5	10	27	90	275	ETP
3 GI-guns 105 in^3	> 1000	2.5	26	82	265	823	ETP
2 GI-guns 105 in^3 (a)	> 1000	3	20	69	-	670	GOMex
2 GI-guns 105 in^3 (b)	> 1000	6	15	50	155	520	GOMex
1 G-gun 210 in^3	> 1000	9	20	78	222	698	Arctic

Based on extant L-DEO modeling, the proposed sound propagation radii for the two 105 in^3 GI-guns are 20 m, 70 m, 160 m, and 670 m for the 190-, 180-, 170- and 160 dB re 1 µPa.rms isopleths, respectively (Table 4.3). Empirical data indicate that for deep water (>1000 m), the L-DEO model tends to overestimate the received sound level at a given distance (Tolstoy et al. 2004). It follows, the proposed sound propagation radii are considered conservative, and it is expected the actual distance at which received sound levels are 160 dB re 1 µPa.rms or greater to be less than that proposed. The proposed sound propagation radii are also consistent with recent modeling of sound propagation the Southern Ocean (Breitzke and Bohlen 2010), and the radii proposed for use in the quantitative analyses in this OEA are assumed reasonable, as well as conservative, estimates of exposure threshold isopleths.

Table 1.3 Sound Propagation Radii for the Dual 105 in^3 GI-gun Array

Acoustic Source	Frequency (Hz)	Source Level (dB re 1 µPa@1m)	Received Levels (dB re 1 µPa.rms) 190	180	170	160
			Distance (meters)			
2 - 105 in^3 GI-guns	10-188	~240 (p-p)	20	70	160	670

1.3.4 Area Ensonified by the GI-gun Array

Considering the contour of the area ensonified to the 160 dB re 1 µP.rms isopleth extends to 1340 m (twice the 670 m radius); that the GI-gun array is towed approximately 2 to 9 m below the surface at a speed of 4 knots (~7.4 km/hr); that the SO surveys will be conducted for 14 days for 24 hrs/day at a speed of 4 knots; it is estimated that the SO survey distance will encompass approximately 1344 Nm (2489 km). Multiplying the total linear distance of the SO survey by the area ensonified to the 160 dB re 1 µP.rms isopleth (1340 m), yields a total ensonified area of ~3335 km^2. For the 170 dB re 1 µPa.rms isopleth the total ensonified area will be ~796 km^2.

1.3.5 Vessel Specifications

All research activities, to include SO profiling and marine mammal monitoring, will be conducted from the RV *Melville*, owned by the U.S. Navy and operated by Scripps Institution of Oceanography of the University of California, San Diego, CA. The RV *Melville* has a length of 97 m, a beam of 14 m, and a maximum draft of 5 m. The vessel is powered by two 1385 hp Propulsion General Electric motors and a 900 hp retracting bow thruster. The RV *Melville* operational speeds of 4 to 6 knots (~7 to 11 km/hr) will be used during SO surveys. When not conducting SO studies, the RV *Melville* will be operated at cruise speeds of approximatley11 knots (~20 km/h), which will occur during transit to and from port to the site of study.

2.0 SPECIES, STATUS, NUMBERS, AND DISTRIBUTION OF MARINE MAMMALS

Thirty-nine species of endemic or migratory cetacea are known to inhabit waters between South Africa and Antarctica. Among the cetacea the southern right, humpback, sei, fin, blue, and sperm whales are listed as endangered under the U.S. Endangered Species Act (ESA). Most of the species occurring in the area spend the austral summer in preferred Antarctic habitats, and the austral winter in areas northward around the east and west coasts of Africa, South America, Australia, and islands of the Indian Ocean.

The cape fur seal is the only pinniped known to have breeding colonies along the southern coast of Africa. It is not listed as threatened or endangered under the U.S. ESA. Cape fur seals are endemic to South Africa, with colonies on islands and patches of mainland along the southern coast.

Population density estimates, distribution patterns, occurrence, status, and critical habitat information are provided for each species of marine mammal known to occur, or that may possibly occur in the study area. Data on marine mammal population distributions, occurrence, status, and critical habitat is derived from: the Ocean Biogeographic Information System (OBIS) Seamap (OBIS-SEAMAP); the

International Union for Conservation of Nature (IUCN 2010); the Convention on the Conservation of Migratory Species of Wild Animals (CMS 2010); NatureServe Explorer (NatureServe 2010); the International Whaling Commission (IWC); and NOAA Fisheries Office of Protected Resources.

Marine mammal population density estimates are based on the Navy Global Marine Species Density Database (GMSDD); unless otherwise cited below. The GMSDD includes the highest quality, spatially modeled, density data where data is available. For all other geographic areas, data were evaluated using a hierarchical approach and a review process to incorporate the best data available. The GMSDD incorporates density from global predictive relative environmental suitability models for geographic areas where no survey data or density estimates exist. The global predictive estimates for areas beyond survey coverage are available in two forms: (1) Sea Mammal Research Unit Limited (SMRUL) that includes survey based density estimates in the prediction of densities estimated elsewhere within Food and Agriculture Organization (FAO) areas; and (2) predictions from Kristin Kaschner which are based on using relative environmental suitability as an index in conjunction with a global mean population estimate determined from literature (Kaschner et al. 2006). The resulting data within the GMSDD provide the best available, single density value for a selected geographic area and time.

2.1 Mysticetes

Blue whale (Balaenoptera musculus)

The blue whale is listed as Endangered under the U.S. ESA and Depleted under the U.S. MMPA throughout its range. Blue whales range from the edge of the Antarctic icepack (40ºS to 78ºS) during the austral summer and north to Ecuador, Brazil, South Africa, Australia, and New Zealand during the austral winter. Populations in Antarctic waters appear to be highest from February to May. The Antarctic form of the blue whale (*B. m. intermedia*) occurs from the Antarctic Polar Front up to and into the ice. The winter distribution is poorly known, though it is presumed animals migrate in winter to lower latitudes, largely due to catches of blue whales off Namibia, South Africa, and Chile. The Southern Hemisphere population for 1996, based primarily on data from the IWC-sponsored whale sightings cruises conducted during 1978 to 2001, was estimated to be 1,700 (860 to 2,900) and to be increasing at the rate of 7.3% (1.4 to 11.6%) (Branch et al. 2004). The global population of blue whales is uncertain, though estimated to be in the range of 5,000 to 13,000, corresponding to about 3 to 11 percent of the 1911 population size (Reilly et al. 2008). Blue whales are not expected to be populous in the area of research activities due to seasonal migration to waters south of 40°S.

Bryde's Whale (Balaenoptera edeni)

The Southern Hemisphere population estimate for Bryde’s whales is ~13,800. Bryde's whales are endemic and year round inhabitants along the southern coast of South Africa. In the South Atlantic, there is a population of Bryde’s whales that summers off the western coast of southern Africa, and migrates to West African equatorial waters in winter. The resident inshore population of Bryde’s whales off South Africa shows some morphological differences from ordinary Bryde’s whales. The main distribution of the inshore population is found between Cape Recife and Saldanha Bay, South Africa.

Common Minke Whale (Balaenoptera acutorostrata), Antarctic Minke Whale (Balaenoptera bonaerensis)

The common minke whale is cosmopolitan and occurs in all oceans from 65°S to 80°N. Data on the occurrence of minke whales in the Southern Hemisphere is somewhat ambiguous with regard to minke whale speciation. The limited survey information available suggests most minke whales recorded were likely *B. bonaerensis*. In summer, Antarctic minke whales are abundant throughout the Antarctic south of 60°S, occurring in greatest densities near the Antarctic ice edge. Antarctic Minke whales have also been seen off Durban, South Africa. Data for summer distributions is limited. Some of the Antarctic minke whale population apparently remains in the Antarctic in winter, though the number of whales has not been quantified. In the southern Atlantic Ocean, *B. bonaerensis* is usually found between 20°S to 65°S. Minke whales in general migrate for great distances seasonally, feeding in and around the Antarctic ice edge during the summer and moving to mating/calving grounds during the winter (7°S to 35°S). Southern Hemisphere estimates for *B. bonaerensis* are 460,000 to 690,000. No accurate estimates for *B. acutorostrata* are available given sighting data does not distinguish between *B. acutorostrata* and more numerous *B. bonaerensis*.

Fin whale (Balaenoptera physalus)

The fin whale is listed as Endangered under the U.S. ESA and Depleted under the U.S. MMPA throughout its range. Fin whale populations peak in the Antarctic in March, and at breeding grounds north of the Antarctic during July and August. While some fin whales are found in the high Antarctic, along with blue, minke, and humpback whales, the bulk of the fin whale summer distribution is in middle latitudes, mainly 40°S to 60°S in the southern Indian Ocean and South Atlantic Ocean. The winter distribution is poorly known, though catch results for fin whales show they have been common off southern Africa during the winter months. In the early 20th century, there were catches off Angola, Congo, and Mozambique. Recent sightings were made in the mid-latitude region (between 55ºS and 61ºS) by the International Whaling Commission's Southern Ocean Whale and Ecosystem Research Program (IWC/SOWER). Fin whales, while common to the area, are not expected to be populous in the area of research of activities due to seasonal migration to Antarctic waters during the austral summer. The current global population estimate is approximately 119,000. The Southern Hemisphere population estimate for fin whales is approximately 15,000 south of 30°S.

Humpback whale (Megaptera novaeangliae)

The humpback whale is listed as Endangered under the U.S. ESA and Depleted under the U.S. MMPA throughout its range. Humpback whales occur worldwide, migrating from tropical breeding areas to polar or sub-polar feeding areas. The Southern Hemisphere population estimate for humpback whales is ~42,000. From June to December humpbacks are common to the South Africa area on their annual migration from the Antarctic to their northern breeding grounds off Madagascar and Mozambique. Humpback populations peak in the Antarctic in March, and are abundant throughout the Antarctic in summer. Populations peak at northern breeding grounds during July and August. In the winter, Southern Hemisphere whales aggregate to specific nearshore breeding areas in the Atlantic, Indian, and Pacific Oceans, two of which extend north of the equator off Colombia in the eastern Pacific and in the Bight of Benin in the Atlantic. Humpback whales are not expected to be populous in the area of research of activities due to seasonal migration to Antarctic waters.

Sei whale (Balaenoptera borealis)

The sei whale is listed as Endangered under the U.S. ESA and Depleted under the U.S. MMPA throughout its range. The austral summer distribution of sei whales in the Southern Hemisphere is found mainly in the zone 40°S to 50°S in the South Atlantic Ocean and southern Indian Ocean, and 45°S to 60°S in the South Pacific. Known wintering grounds include a number of former low latitude whaling grounds, such as northeastern Brazil at 7°S, Peru at 6°S, and in earlier years off Angola and the Congo. Catches off western South Africa (Donkergat) and eastern South Africa (Durban) shown peaks in the austral spring and autumn, suggestive of populations on migratory routes. Sei whales are not expected to be populous in the area of research of activities due to seasonal migration to waters south of 45°S. As of 2006, worldwide population was ~54,000, about a fifth of its pre-whaling population. The IWC 1996 estimate for sei whales south of 30°S was 9,718 based upon survey data between 1978 and 1988.

Table 2.0 provides estimates of the average, minimum, and maximum marine mammal population densities in the area of the proposed study during the austral summer, anticipated occurrence of each species in the area of research during the austral summer, primary habitat(s), and U.S. ESA listing status.

Table 2.0 Mysticete Population Density Estimates

		Number of Individuals per km²				
Mysticetes	**ESA**	**Average (best)**	**Minimum**	**Maximum**	**Occ.**	**Habitat(s)**
Antarctic Minke Whale (Balaenoptera bonaerensis)		0.00409	0.00269	0.00631	r	C/P
Blue Whale (Balaenoptera musculus)	E	0.00003	0.00001	0.00004	r	C/P
Bryde's Whale (Balaenoptera edeni)		0.00026	0.00004	0.00043	c	C/P
Common Minke Whale (Balaenoptera acutorostrata)		0.03094	0.01995	0.04828	r	C/P
Fin Whale (Balaenoptera physalus)	E	0.00859	0.00015	0.01496	c	CS/S/P
Humpback Whale (Megaptera novaeangliae)	E	0.00010	0.00007	0.00011	r	NrSh/Bnks
Sei Whale (Balaenoptera borealis)	E	0.00310	0.00030	0.00493	r	P

r – Rare; c – Common; C – Coastal; P – Pelagic; CS – Continental Shelf; S – Continental Slope; NrSh – Nearshore; Bnks – Banks; Occ. – Occurrence; E – U.S. ESA Listed as Endangered

2.2 Odontocetes

Arnoux’s Beaked Whale (Berardius arnuxii)

Sightings of this species in the Antarctic Peninsula, though rare, suggest this species may spend the austral winter in the Antarctic region (Friedlaender et al. 2010). Arnoux's beaked whales are typically found in cold water south of 34°S, and have been observed in close proximity to the ice edge, usually in groups of less than 15. Sightings of large numbers have been reported in the western Antarctic coastal area during the austral spring. They are generally found in deep, cold, and subpolar waters, and areas with steep slopes beyond the continental shelf. While they occur both north and south of the Antarctic Polar Front, there is no information available on seasonal shifts in populations. Arnoux’s beaked whales are not expected to be significantly populous in the area of research activities as their primary habitat in this region are waters of the Antarctic.

Cuvier's Beaked Whale (Ziphius cavirostris)

Cuvier's beaked whales are widely distributed in offshore waters of all oceans, from the tropics to the temperate and polar regions in both hemispheres, save for shallow water areas and very high-latitudes, occurring between approximately 60°N and 55°S. There is insufficient data on distribution in the South Africa region, though global population estimates approach 100,000. Cuvier's beaked whales, like all beaked whales, appear to prefer deep waters for feeding, exhibiting dives of up to 40 minutes. They are seldom found near-shore, and appear to prefer waters near continental slopes with steep bathymetry. Their presence in the study area is assumed to be year round.

Dwarf Sperm Whale (Kogia sima)

No estimates of global abundance exist for dwarf sperm whales, and their migratory patterns are not well understood, though in the Southern Hemisphere their range is known to include waters of the study area.

Gray's Beaked Whale (Mesoplodon grayi)

Gray’s beaked whale is considered a Southern Hemisphere cool temperate species, and appears to prefer circum-Antarctic waters. Most records for Gray’s are from south of 30°S. There are ample records of sightings from Antarctic and sub-Antarctic waters. During summer months they are observed near the Antarctic Peninsula, and waters along the continental shore. Most stranding records are from New Zealand, southern Australia, South Africa, Argentina, Chile, and Peru. Gray's beaked whale is primarily observed in deep waters beyond the edge of the continental shelf. In the austral summer they appear near the Antarctic Peninsula and along the shores of the continent. The species is considered to rarely be seen at sea. Gray’s beaked whales are not expected to be populous in the area of research of activities as their primary habitat, during the austral summer, are waters of the Antarctic.

Hector's Beaked Whale (Mesoplodon hectori)

Hector's beaked whale is considered to be a Southern Hemisphere cool temperate species. There are few records for this species, though the records that do exist are from strandings in South Africa, southern South America, southern Australia, and New Zealand.

Pygmy Right Whale (Caperea marginata)

Pygmy right whales have a circumpolar distribution preferring the temperate waters of the Southern Hemisphere, between 30°S and 55°S, and extending to 20°S in the Benguela system off the southwest African continental shelf. It is one of the least known baleen whale species, and there is marginal data on which to estimate population size. There are few confirmed records of pygmy right whales at sea, though strandings have been reported from Argentina, Falkland Islands (Malvinas), Namibia, and South Africa. They are rarely sighted and information on this species is lacking.

Pygmy Sperm Whale (Kogia breviceps)

Pygymy sperm whales are rarely observed and little survey information exist for this species. Their preferred habitat is believed to be the open ocean. The range of *Kogia breviceps* is poorly known, though as with many species with insufficient population and range data, a lack of records may be more due to inconspicuous behaviors rather than rarity. While they are known to occur in the South

Africa region (Eastern Cape Province, KwaZulu-Natal, Northern Cape Province, Western Cape Province), there is sparse information on stock densities and preferred habitat in this region. Strandings in some areas (e.g., Florida and South Africa) suggests their abundance may not be as uncommon as sightings and surveys suggest. Distribution of this species in area of research during the time of study is not well known.

Southern Bottlenose Whale (Hyperoodon planifrons)

There are an estimated 599,300 beaked whales south of the Antarctic Convergence (~50°S) in January, most of which are considered to be southern bottlenose whales. They are most frequently seen in summer within about 100 km of the Antarctic ice edge. Most sightings occur in the region of 57°S to 70°S, and there are known areas of concentration in the region between 58°S and 62°S in the Atlantic and eastern Indian Oceans. There have also been reported sightings in the steep thermocline between the Agulhas current and cold Antarctic water masses (Cockcroft et al. 1990). There is limited data on distribution in the South Africa region, though their normal range during the austral summer is south of the region of study, in Antarctic waters.

Southern Right Whale (Eubalaena australis)

The southern right whale is listed as Endangered under the U.S. ESA and Depleted under the U.S. MMPA throughout its range. Southern right whales are common to the study area and seen with great predictability from May to October. The nearshore areas of South Africa are a current breeding ground that extends along the coast to Cape Point, South Africa. Southern right whales calve in this region during May and June. Calves are born from June to October with a peak in August. They migrate southward in November/December to the polar regions of the Southern Hemisphere, and found mainly in the regions of 40°S to 50°S, though range well into the Antarctic as far as 65°S. While populations move southward during the austral summer, southern right whales are known to occur in the study area year round. The latest 1991 estimate for the worldwide population was ~25,000 whales. In the Southern Hemisphere south of 30°S the population is estimated to be ~9,700, with far fewer, ~600, south of 60°S. The southern right whale population in the region of South Africa is estimated at ~ 3,400 individuals. Right whales are predominantly found along the Cape coast between Muizenberg and Woody Cape, and in the area of Hermanus, between June and November. Southern right whales are not expected to be particularly populous in the area of research of activities due to seasonal migration to waters south of 40°S.

Sperm Whale (Physeter macrocephalus)

The sperm whale is listed as Endangered under the U.S. ESA and Depleted under the U.S. MMPA throughout its range. They can be seen in nearly all marine regions, from the equator to high latitudes. Sperm whales range between the northern and southern polar pack ice, though most frequently inhabit tropical and temperate waters with depths >1000 m, over the continental shelf, slope, and in pelagic waters. Females and young are usually restricted to waters at latitudes lower than about 40ºS and to areas where sea surface temperatures are greater than about 15ºC (Rice 1989). Both sexes are known to range in temperate and tropical areas, however, only adult males are known to populate higher latitudes. Sperm whale migratory patterns are not well understood. In mid-latitudes there appears to be a seasonal north/south migratory trend where sperm whales move poleward in the summer, though not into the higher latitude waters with ice. Their occurrence in the area during the time of research activities is not easily discerned from the information available. Their presence in the study area is presumed to be year round. Current global estimates range from 106,000 to 1,500,000, with the assumed population to be in the range of 360,000. Sperm whale populations estimates (from the late 1990s) for south of 30ºS are ~128,000.

Strap-toothed Whale (Mesoplodon layardii)

Strap-toothed whales are distributed in the cold temperate waters of the Southern Hemisphere, primarily between 35°S and 60°S. There are reported strandings in South Africa, Australia, Tasmania, New Zealand, the Kerguelen Islands, Heard Island, Argentina, Uruguay, Brazil, and the Falkland Islands. The seasonality of the strandings suggest the species may be migratory, following the typical migrations from the northern latitudes in winter, to the southern latitudes in summer, though preferred habitats are not well known. Like all beaked whales, they occur primarily in deep waters beyond the edge of the continental shelf. There is no information on the distribution of this species for the site study, however, they are considered common to the area in which research will conducted.

True's Beaked Whale (Mesoplodon mirus)

True’s beaked whales occur in the southern Indian Ocean, the waters of Madagascar, southern Australia, and the Atlantic coast of Brazil. They have been only rarely identified at sea, and there are no estimates of regional of global abundance. *M. mirus* is considered likely a deep-water pelagic species, like other ziphiids. There are approximately 20 stranding records worldwide, which is considered comparatively few, and the species appears to be rather rare. However, a mainly offshore habitat and the difficulty in identifying *M. mirus* at sea may also be account for their perceived rarity. The species appears to prefer waters north of 30°N and south of 30°S.

Common Bottlenose Dolphin (Tursiops truncatus)

There are considered two populations of bottlenose dolphin in South African waters: One form is found in primarily shallow water coastal habitats, the other found in deep oceanic waters. This species does not generally range pole-ward beyond 45°. The study area is the southern limit of their range, and they are considered common to the region in which research will be conducted.

Dusky Dolphin (Lagenorhynchus obscures)

The dusky dolphin ranges in coastal waters of southern Africa from Angola south to Cape Agulhas. In the Southern Ocean, a total of 2,665 dusky dolphins in 27 schools were observed during minke whale assessment cruises between 1978/79 and 1987/88. These observations were made while in transit between home ports and the Antarctic, though no abundance estimates were calculated. Although oceanic, sightings are often associated with near shore, island, and bank environments.

False Killer Whale (Pseudorca crassidens)

False killer whales are found in tropical to warm temperate zones, generally in relatively deep, offshore waters of all three major oceans, and their range is considered to extend south to ~30°S. Distribution data for this species in the study area is unavailable, and it is not possible to estimate their occurrence in the area of research during the time of study.

Fraser's Dolphin (Lagenodelphis hosei)

Fraser's dolphins appear to be more common near the equator in the eastern tropical Pacific. This species appears to be relatively scarce in the Atlantic Ocean, although it is seen from the Lesser Antilles, the Gulf of Mexico, and Venezuela. Infrequent sightings of Fraser's dolphin have been reported in the Indian Ocean near the east coast of South Africa, Madagascar, Sri Lanka, and Indonesia. This species is not expected to be encountered in the area of proposed research activities.

Heaviside's Dolphin (Cephalorhynchus heavisidii)

Heaviside's dolphins are endemic to coastal waters of the West African seaboard. Sightings of dolphins have been made from the breaker zone to about 45 nautical miles offshore in waters of no more than 180 m in depth. Heaviside's dolphins prefer shallow coastal waters within 8-10 km of the shore. As is the case with other members of the genus, heaviside's dolphin seems to be confined to the continental shelf of South Africa and Namibia (Best and Abernethy 1994). Heavside's dolphins are not expected to be encountered during the proposed research activities given studies will occur beyond their normal range.

Hourglass Dolphin (Lagenorhynchus cruciger)

Hourglass dolphins are commonly observed south of the Antarctic Convergence (~50ºS). It is considered circumpolar in pelagic waters of the sub-Antarctic and Antarctic zones. Most records for hourglass dolphins are between 45°S and 65°S. Abundance estimates are ~144,300 for waters south of the Antarctic Convergence. This species is not expected to be common to the area of research activities.

Indo-pacific Bottlenose Dolphin (Tursiops aduncus)

Indo-pacific bottlenose dolphins are widespread along the eastern coast of Africa and Madagascar. While they can be found in waters 200 m deep, large concentrations of this species are known to regions with large shallow-water bodies, and they are encountered most frequently in waters < 100 m in depth. They seem to prefer water temperatures of 20 to 30°C, at a minimum of 12°C. There are an estimated 900 indo-pacific bottlenose dolphins (*Tursiops aduncus*) in the South Africa region, and 600,000 globally. Indo-pacific bottlenose dolphins are not expected to be encountered in the area of study.

Indo-pacific Hump-backed Dolphin (Sousa chinensis)

The Indo-pacific humpback dolphin occurs from False Bay in Cape Province, and north along the coast of eastern Africa, including Madagascar. *S. chinensis* is rarely found more than a few kilometers from shore, preferring coastal areas with lagoons, estuaries, and reefs. Animals sometimes enter rivers, though rarely more than a few kilometers upstream and usually within the tidal range. This species is not expected to be common to the area of proposed research activities.

Killer Whale (Orcinus orca)

Killer whales (orca) are considered the most cosmopolitan cetacean and can be found in virtually all marine regions from the equator to polar waters. Orcas are most common in the Antarctic and sub-

Antarctic in the Southern Hemisphere, although they are periodically spotted off the southern coast of South Africa. Population densities are known to vary within Antarctic waters, ranging from very abundant to uncommon, with higher densities closer to the ice edge. Recent population estimates are approximately 25,000 for waters south of 60ºS, however, there remain uncertainties as to coverage of areas in the pack ice, and true abundance could be higher. Killer whales are assumed to occur in the study area year-round.

Long-beaked Common Dolphin (Delphinus capensis)

There are an estimated 15,000 to 20,000 long-beaked common dolphins off of eastern South Africa. Long-beaked common dolphins are capable of dives to 280 m and holding their breath for up to 8 minutes. This species prefers shallow, tropical, subtropical and warmer temperate waters closer to the coast, usually 90 to 180 km, and waters of the continental shelf. This species is not expected to be common to the area of research activities.

Long-finned Pilot Whale (Globicephala melas)

Long-finned pilot whales occur in temperate and subpolar zones around the world. The circum-Antarctic subpopulation occurs as far south as the Antarctic Convergence to ~68°S. There is limited data on stock densities in the region of study, though there are an estimated 200,000 long-finned pilot whales in summer south of the Antarctic Convergence (~50°S). Long-finned pilot whales are not expected to be populous in the area of research of activities due to seasonal habitat preference of waters south of 50°S.

Pantropical Spotted Dolphin (Stenella attenuata)

Pantropical spotted dolphins are distributed in tropical and warm-temperate waters around the world, from roughly 40°N to 40°S, although it is much more abundant in the lower latitude portions of its range. There is sparse data on population and distribution for the waters of southern Africa. The anticipated frequency of encounter with this species cannot be determined from available data.

Pygmy Killer Whale (Feresa attenuata)

The pygmy killer whale occurs in warm deep waters typically beyond the edge of the continental shelf, and rarely close to shore. This species is mainly tropical, though occasionally found in temperate regions, generally not ranging north of 40°N or south of 35°S. The distribution of *F. attenuata* is poorly known due to sparse records worldwide. Of these, there are records of pygmy killer whales in the cool water west coasts of southern Africa and Peru, though these occurrences are considered to be extralimital. There is sparse data on stock densities in the study area. The area of the proposed research is south of the southern limit of their normal range, and pygmy killer whales are not expected to be significantly populous in the area of study.

Risso's Dolphin (Grampus griseus)

Risso’s dolphin is widely distributed, inhabiting primarily deep waters of the continental slope and outer shelf. They range from the tropics to temperate regions in both hemispheres, and are found in the offshore waters of South Africa, inhabiting deep oceanic and continental slope waters 400 to1000 m deep. As such, Risso’s dolphin is expected to be common in the area of study. While pelagic, Risso’s populations off the east and west coasts of North America appear to migrate along the coast in shallow coastal waters, and this has also been observed for animals off South Africa.

Rough-toothed Dolphin (Steno bredanensis)

Rough-toothed dolphins are rarely seen ranging north of 40°N or south of 35°S, and are distributed in tropical and warm temperate waters around the world. There are limited records on occurrence and distribution for this species in waters of southern Africa. The anticipated frequency of encounter with this species cannot be determined from available data.

Short-beaked Common Dolphin (Delphinus delphis)

Short-beaked common dolphins are abundant and occur in the Indian Ocean around southeastern Africa from nearshore to thousands of kilometers offshore. There is some discrepancy as to speciation: Previous records of this species in other parts of the Indian Ocean and in waters of Taiwan are now thought to have been of long-beaked common dolphins (*D. capensis*). After a critical re-examination of records of the genus *Delphinus* from the western Atlantic Ocean, discrepancies were found that challenge commonly accepted distribution patterns (Cockcroft and Peddemors 1990; Filby et al. 2010; Jefferson et al. 2009; Olavarria et al. 2010; Oviedo et al. 2010). When considering only validated records it was suggested that populations *D. delphis* may occur in only three areas: Off the east coast of the U.S. and Canada, from 32°N to about 47° to 50°N; in the Caribbean off central-eastern Venezuela; and off eastern South America, south of 20°S. This species, found in pelagic habitat, may be common to the area of research activities.

Short-finned Pilot Whale (Globicephala macrorhynchus)

Short-finned pilot whales are pelagic, range from warm temperate to tropical areas of the world, and generally found in deep offshore waters over the outer continental shelf or continental slope. They do not usually range north of 50°N or south of 40°S. There is noted distributional overlap with the long-finned pilot whale (*G. melas*), which appears to prefer the cold to temperate waters of the North Atlantic, Southern Hemisphere, and western North Pacific. There is sparse data on their distribution in the region of study, though global population estimates range up to 65,000. As with pygmy killer whales, the area of the proposed research is south of the southern limit of their range, and short finned pilot whales are not expected to be significantly populous in the study area.

Southern Right Whale Dolphin (Lissodelphis peronii)

The southern right-whale dolphin is a circumpolar species occurring in the sub-Antarctic between 40°S and 55°S. It ranges north to 23°S in the Benguela Current off Walvis Bay in Namibia, South Africa. They inhabit almost exclusively temperate waters, with most records from north of the Antarctic Convergence. There are limited estimates on distribution for the southern right whale dolphin, and little is known of the subpopulation structure or status of the species.

Spinner Dolphin (Stenella longirostris)

Spinner dolphins are pantropical, occurring in all tropical and subtropical waters around the world between roughly 40°N and 40°S. Their South African distribution is poorly known, and there has been a noted lack of recent sightings, strandings, or by-catches off West Africa. Most reported sightings are from the coast of Zanzibar in the Western Indian Ocean. There is little population distribution data for the area of study, and their occurrence in the region of study is unknown.

Striped Dolphin (Stenella coeruleoalba)

The striped dolphin is a cosmopolitan pelagic species distributed world-wide in tropical and temperate waters from 50°N to 40°S, occurring beyond the continental shelf at depths of over 1,000 m. Its distribution in the region is correlated with the warm Agulhas Current. While they are considered common to the area of study year round, there is sparse data on population distribution for the area in which research activities will be conducted.

Table 2.1 provides estimates of the average, minimum, and maximum marine mammal population densities in the area of the proposed study during the austral summer, anticipated occurrence of each species in the area of research during the austral summer, primary habitat(s), and U.S. ESA listing status.

Table 2.1 Odontocete Population Density Estimates

		Number of Individuals per km²				
Odontocetes	**ESA**	**Average (best)**	**Minimum**	**Maximum**	**Occ.**	**Habitat(s)**
Arnoux's Beaked Whale (Berardius arnuxii)		0.0045	0.0001	0.0102	r	DW
Cuvier's Beaked Whale (Ziphius cavirostris)		0.0035	0.0006	0.0048	c	P
Dwarf Sperm Whale (Kogia sima)		0.0001	0.0000	0.0001	i	CS/DW
Gray's Beaked Whale (Mesoplodon grayi)		0.0033	0.0005	0.0046	r	DW
Hector's Beaked Whale (Mesoplodon hectori)		0.0028	0.0003	0.0041	r	DW
Pygmy Right Whale (Caperea marginata)		0.0000	0.0000	0.0001	i	CS/P
Pygmy Sperm Whale (Kogia breviceps)		0.0000	0.0000	0.0000	i	CS/DW
Southern Bottlenose Whale (Hyperoodon planifrons)		0.0064	0.0001	0.0116	r	DW
Southern Right Whale (Eubalaena australis)	E	0.0001	0.0000	0.0001	c	C/P
Sperm Whale (Physeter macrocephalus)	E	0.0058	0.0009	0.0070	c	P/DW
Strap-toothed Whale (Mesoplodon layardii)		0.0028	0.0005	0.0046	c	DW
True's Beaked Whale (Mesoplodon mirus)		0.0029	0.0004	0.0044	c	DW
Common Bottlenose Dolphin (Tursiops truncatus)		0.0424	0.0108	0.0979	c	C/P
Dusky Dolphin (Lagenorhynchus obscurus)		0.0001	0.0000	0.0003	r	C/P
False Killer Whale (Pseudorca crassidens)		0.0002	0.0001	0.0004	i	P
Fraser's Dolphin (Lagenodelphis hosei)		n.a.	n.a.	n.a.	-	DW
Heaviside's Dolphin (Cephalorhynchus heavisidii)		0.0035	0.0009	0.0071	r	C/DW
Hourglass Dolphin (Lagenorhynchus cruciger)		0.0010	0.0000	0.0020	r	C/P
Indo-pacific Bottlenose Dolphin (Tursiops aduncus)		n.a.	n.a.	n.a.	-	C/CS
Indo-pacific Hump-backed Dolphin (Sousa chinensis)		n.a.	n.a.	n.a.	-	C
Killer Whale (Orcinus orca)		0.0090	0.0032	0.0146	c	Ub
Long-beaked Common Dolphin (Delphinus capensis)		0.0002	0.0000	0.0006	c	C/CS
Long-finned Pilot Whale (Globicephala melas)		0.0539	0.0013	0.1019	r	CS/S/P
Pantropical Spotted Dolphin (Stenella attenuata)		0.0060	0.0001	0.0138	i	C/P
Pygmy Killer Whale (Feresa attenuata)		0.0004	0.0000	0.0009	r	DW
Risso's Dolphin (Grampus griseus)		0.0631	0.0433	0.1007	c	DW

Rough-toothed Dolphin (Steno bredanensis)	0.0005	0.0000	0.0011	r	DW
Short-beaked Common Dolphin (Delphinus delphis)	0.2397	0.1278	0.3760	c	CS/S/P
Short-finned Pilot Whale (Globicephala macrorhynchus)	0.0258	0.0086	0.0408	r	P
Southern Right Whale Dolphin (Lissodelphis peronii)	0.0086	0.0008	0.0206	c	DW
Spinner Dolphin (Stenella longirostris)	0.0049	0.0040	0.0103	c	C/P
Striped Dolphin (Stenella coeruleoalba)	0.1877	0.0276	0.3066	c	CS/S/P

r – Rare; c – Common; i-Indeterminate; C – Coastal; P – Pelagic; CS – Continental Shelf; S – Continental Slope; NrSh – Nearshore; Bnks – Banks; Ub-Ubiquitous; DW-Deep Water; Occ. – Occurrence; E – U.S. ESA Listed as Endangered; n.a. – Not considered likely to occur in area of research activities

2.3 Pinnipeds

Cape fur seal (Arctocephalus pusillus)

The cape fur seal is the only pinniped known to have breeding colonies along the South African coast. It is not listed as threatened or endangered under the U.S. ESA. Cape fur seals are endemic to southern Africa with colonies on islands and patches of mainland around the coast from Namibia to South Africa. About 60 percent of the sub-continental population, some 700,000 to 800,000 seals are found along the Namibian coast. Cape fur seals have been recorded up to 220 km offshore, though their normal range is ~160 km out to sea from shore. Table 2.2 provides estimates of known population densities in the area of the proposed research, and anticipated occurrence of each species during the January 2012 period of the proposed research activity.

Table 2.2 Pinniped Population Density Estimates

	ESA	Number of Individuals per km²	Estimated Occurrence in Area During January
Cape fur seal (Arctocephalus pusillus)		0.037	r

r- Rare

3.0 TYPE OF INCIDENTAL HARASSMENT AUTHORIZATION REQUESTED

Pursuant to Section 101(a)(5)(D) of the U.S. MMPA the NRL is requesting authorization for the incidental harassment of 2413 cetacea for conduct of the proposed research. Considering inclusion of the planned monitoring and mitigation measures, potential adverse effects on marine mammals are expected to be limited to some masking effects and avoidance behavioral responses in the areas ensonified by the GI-gun array. Short-term changes in behavior consistent with, and limited to the U.S. MMPA definition of Level B incidental harassment, are considered possible, and determined the most likely adverse effects that may result from the proposed action. All potential take, by incidental harassment only, is expected to result from the operation of the low energy GI-gun array; take is no take expected to result from the use of the MBES, SBP, ADCPs, or from collision of the vessel with marine mammals. Routine vessel operations are currently held to have negligible impact on marine fauna such that no taking of marine mammals is expected in association with the routine vessel operations. The proposed action is expected to have negligible impact on marine invertebrates, fishes, or fisheries, and no indirect effects that may result in harassment are expected. No other adverse effects are anticipated to occur.

To be eligible for an IHA under the U.S. MMPA the proposed "taking" must have negligible impacts. The National Marine Fisheries Service (NMFS) has defined "negligible impact" in 50 CFR 216.103 as "an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival." Analysis of the proposed action has determined that the overall adverse effects that may result would meet the conditions of negligible impact. Given several species of marine mammals are U.S.-ESA listed as endangered, consultation with NMFS will be necessary under Section 7 of the U.S.-ESA for actions that may affect listed species.

4.0 NUMBER OF MARINE MAMMALS THAT MAY BE TAKEN

Exposure Assessment Metrics

NMFS has determined that for assessing adverse effects related to the introduction of acoustic energy into the marine environment using acoustic threshold criteria in combination with corresponding sound propagation radii is the most effective way to quantitatively estimate the effects of an action, and consistently apply measures to avoid or minimize the potential adverse impacts of an action. Acoustic threshold criteria are used in two ways: (1) To calculate the area that will be ensonified by an acoustic source to or above an established threshold, and, based on the estimated population density of marine fauna and the area ensonified by the acoustic sources over the duration of the study, estimate the number of marine fauna that may be harassed as a result of the action; and (2) to establish an acoustic exposure mitigation zone (e.g., if an animal enters an area determined to be ensonified above the level of an established threshold, the acoustic source is powered down or shut down).

The acoustic threshold criteria used for determining the potential adverse effects to marine mammals (Table 4.0) are those previously used by the National Marine Fisheries Service (NMFS) for evaluating activities using impulsive sound sources (e.g., see Southall et al. 2007), such as the GI-guns employed in the SO survey in the proposed action. Threshold criteria normally used for sound generated by GI-guns are:

- Level A (injury) harassment may occur when cetaceans and pinnipeds are exposed to sound pressures ≥180- and 190 dB re 1 μPa.rms, respectively.

- Level B (behavioral) harassment may occur when cetaceans and pinnipeds are exposed to ≥160- and 170 dB re 1 μPa.rms, respectively.

NMFS considers the above threshold criteria "conservative", and that harassment, as well as TTS, as a result of a single impulsive sound exposure may occur at much higher levels (NMFS 2010c). As summarized by Southall et al. (2007), current data implies that TTS is unlikely to occur in most odontocetes (and likely mysticetes) unless they are exposed to a sequence of several air-gun pulses at received levels substantially exceeding 180 dB re 1μPa.rms.

Table 4.0 Exposure Threshold Criteria for Marine Mammals and Fish

	Level A: Injury dB re 1 μPa.rms	Level B: Behavioral Harassment dB re 1 μPa.rms
Cetaceans	180	160
Pinnipeds	190	170
Fish	206	150

Exposure estimates are based on marine mammal population density estimates (given in Section 2) relative to the total area ensonified by the GI-gun array (presented in Section 1.3.4), and evaluated for exposure to the 160 dB re 1 μPa.rms threshold/isopleth for cetacea. Multiplying the total area ensonified during the SO survey by the population density estimate for each species, yields the estimated number of marine mammals exposed to sound pressures ≥160 dB re 1 μPa.rms. As described in Section 1.3.4; for the 160 dB re 1 μPa.rms threshold the total ensonified area is ~3,335 km^2. The estimated total area of ensonification assumes no areas of overlap during the SO survey transects, which will cover a total distance of 2489 km.

The body of knowledge on the response of cetacea to air-gun sounds is somewhat limited, however, it is generally understood that mysticetes tend to keep a greater distance from vessels conducting seismic surveys as compared to most species of odontocetes. The comparatively different responses exhibited by mysticetes and odontocetes is perhaps not surprising given mysticetes (as a suborder) are more sensitive to lower frequency sounds, as those generated by air-guns.

The primary auditory sensitivity of mysticetes is from 7 Hz to 30 kHz, and communicative sounds in the frequency range of 10 Hz to 31 kHz. Most odontocetes have been classified as belonging to "mid-frequency" and "high-frequency" functional hearing groups (Southall et al. 2007), given odontocetes (collectively) have functional hearing from about 150 Hz to 180 kHz, and are generally understood to be insensitive to lower frequency sound. Small to moderate sized odontocetes have relatively poor hearing sensitivity at frequencies below 1 kHz, though good sensitivity at and above several kHz. Most of the acoustic energy in the sound generated by an air-gun, which is broadband, is low frequency, below 200 Hz. A considerably lower level of energy is generated up to 1 kHz, and much smaller amounts of energy up to ~150 kHz. It follows, as a suborder, mysticetes are more sensitive to the sound pressure generated by air-guns, relative to odontocetes. Several observations describing the comparatively different behavioral responses of mysticetes and odontocetes to air-gun sounds are summarized following.

Mysticetes

Mysticetes, in general, tend to avoid sound generated by air-guns, though responses are varied and appear dependent upon species, location, and given species activity during the time at which seismic surveys are conducted. By example; blue, fin, minke, and sei whales sighted during seismic surveys have appeared to exhibit little variance in behavior relative to when air-guns were and were not operating (Moulton et al. 2006; Moulton and Miller 2005; Stone and Tasker 2006). In contrast, other studies suggest that a substantial portion of the populations of gray, humpback, and bowhead whales exhibited avoidance to air-gun sounds at received levels of ~160 to170 dB re 1 µPa.rms. Studies by McCauley et al have shown that localized displacement of humpback whales during migration (~4 km by traveling pods and 7 to12 km by pods of cow-calf pairs) occurred in response to air-gun sounds at received levels of ~140 dB re 1 µPa.rms (McCauley et al. 2000; McCauley et al. 1998).

Where the degree of response appears to vary among species, activity at the time of exposure also seems to be a determinant factor. A study by Malme et al. (1985) concluded there was no clear evidence of avoidance behaviors in humpback whales while foraging off of the coast of Alaska, even at received levels up to 172 re 1 µPa.rms, levels that are clearly audible. As with humpback whales, studies suggest bowhead whales also appear less responsive to air-gun sounds while engaged in foraging (Harris et al. 2007; Miller et al. 2005), typically exhibiting avoidance response at sound levels of ~150 to178 dB re 1 µPa.rms. Studies by Miller et al. (1999) and Richardson et al. (1999) likewise suggest foraging, as well migratory conditions, may determine the degree of behavioral response; during migration bowhead whales appear to be more responsive to air-gun sounds, exhibiting substantial avoidance of a seismic vessel at sound levels of ~120 to 130 dB re 1 µPa.rms.

These empirical observations are rather limited, but suggest mysticete behavioral responses are relative according to foraging and migratory activities, as well as sex and calving status (Arnold 1996; Costa et al. 2003; Croll et al. 2001; Frankel 2005; Frankel and Clark 1998; McCauley et al. 2000; McCauley et al. 1998; NRC 2005; Richardson et al. 1999; Southall et al. 2007; Wartzok 2009; Williams et al. 2002).

Odontocetes

Odontocetes in general exhibit avoidance of vessels while air-guns are operating (Finneran et al. 2005; Finneran et al. 2000; Stone and Tasker 2006; Weir 2008), however, as with mysticetes, there is no consistent response, which is due in part to the activity odontocetes are engaged in at the time of exposure, yet also to the auditory frequencies to which various species of odontocetes are sensitive to. Odontocetes (collectively) have functional hearing in the range of 150 Hz to 180 kHz, and are generally understood to be insensitive to lower frequency sound. Small to moderate sized odontocetes, which describes many of the delphinid species, have relatively poor hearing sensitivity at frequencies below 1 kHz, though good sensitivity at and above several kHz. The majority of the acoustic energy generated by airgun arrays is at low frequencies, with most of the energy at frequencies below 200 Hz, considerably lower energy at levels up to 1 kHz, and much smaller amounts of energy at frequencies up to ~150 kHz. Thus, most of the acoustic pressure generated by air-guns is at frequencies that are at the upper auditory limit for the Delphinidae family.

While, in general, odontocete reactions to large air-gun arrays vary, the avoidance distance for delphinids, which have poor auditory sensitivity at frequencies below 1 kHz, is now understood to be comparatively less than that for large odontocetes and mysticetes. Empirical observations over the last several years indicate that delphinids are more frequently observed within the 160 dB re 1 µPa.rms isopleth during seismic survey operations (e.g., see LGL 2009, 2010b), and reports by personnel operating air-guns, and marine mammal observers, suggest that delphinids are more commonly observed in the vicinity of vessels when seismic surveys are underway (Barkaszi et al. 2009; Holst et al. 2006; Richardson et al. 2009; Stone 2003; Stone and Tasker 2006; Weir 2008).

Some species of dolphin have been observed to ride the bow wave of a vessel while air-guns were in operation (Moulton and Miller 2005). Similarly, during a seismic survey off California employing a rather large array of 18 air-guns, smaller odontocetes exhibited no significant behavioral changes relative to when air-guns were, or were not, operating (Arnold 1996). In terms of the risk of injury, NMFS estimates that exposure to several air-gun pulses at received levels near 200 to 205 dB (rms) might result in slight TTS in delphinids, assuming the TTS threshold is a function of the total received acoustic energy (e.g., see NMFS 2008; Southall et al. 2007).

Estimates of the Numbers and Species of Marine Mammals Potentially Taken

One method of estimating takes assumes marine mammals are uniformly distributed throughout a given area, although this is not representative of the real world distribution of marine mammals in any given geographic region. Marine mammals are typically found grouped in pods, concentrate around preferred breeding and foraging habitats, and most species follow seasonal migratory patterns and routes. However, due to lack of substantive information on marine mammal population distributions and densities in the area of the proposed action, informed assumptions on distribution patterns cannot be made, and exposure estimates are based on uniform distribution of marine mammals over the area for which population data is available. Bearing these factors in mind, the exposure estimates provided are considered reasonable approximations of potential exposure, and based on the best available information available.

Marine mammal population density estimates for the area and time of year of study provide species of cetacea that would be expected to be present in the study area during the time research activities will conducted. Many, though not all, species are unlikely to be significantly populous in the area of study during January, when research will be conducted, as the austral summer migration finds many of the migratory species in the Southern Ocean in Antarctic waters, typically south of 40°S, which borders the southern latitude of the area of study. The only commonly sighted (to our knowledge) whales year round off the South African coast is an in-shore sub-species of Bryde's whale and the Southern right whale. In general, whales are most populous in the study area during the austral winter months, from approximately June to November, and populations at their lowest during the austral summer.

Tables 4.1 and 4.2 provide estimates of the average (considered the best estimate), minimum, and maximum marine mammal population densities in the area of the proposed study during the austral summer, anticipated occurrence of each species, and requested takes authorization. For all species evaluated, average population density estimates were used for calculation of the number of marine mammals that may be exposed. NMFS has used best (or average) population density estimates when analyzing the allowable harassment for U.S. ESA-listed marine mammals incidental to marine seismic surveys for scientific research purposes (e.g., see NMFS 2010c, 2011c). The results of the monitoring reports from these seismic surveys, and others, show that the use of the best (average) estimate is appropriate for provision of reasonable estimates of exposure and harassment. Requested takes estimates are based on Navy exposure criteria, which determines take at 0.5 animals exposed for non U.S.ESA-listed marine mammals, and 0.05 animals exposed for U.S.ESA-listed species.

Because extant mathematical models poorly simulate and predict the natural meander of the AC, ARC, and ARC/ACC frontal system, and due to unpredictable weather conditions, it is not possible to accurately predict the exact location where SO survey transects will occur (see (Sections 2.2.1 and 2.2.2). For this reason, the minimum, average, and maximum population densities given in Tables 5.0 and 5.1 are the mean of the population densities for each species within the coordinates of 36°S to 43°S, and 19°E to 30°E. The mean of the average population densities over this area were used given the uncertainty of the exact location of the area of study (discussed in further detail below), which cannot be predetermined in January/February 2012 due to the natural meander of the ARC and ACC currents, and it follows, the ARC/ACC front. Hence, because the ARC/ACC frontal region is located within the general boundaries of approximately 36°S to 43°S, and 19°E to 30°E, the mean of the average population density values for each square kilometer of this region were used in order to (1) capture the uncertainty as to exactly where the SO survey will take place, and (2) the inherent uncertainty in marine mammal population density estimates.

While it is estimated that the front will be phase-locked between 36°S to 40°S, and 21°E to 27°E, the position of the front can vary by up to 100 km (generally west, east, and south of this estimated location), and because the precise location of SO survey transects cannot be known in advance, it is not possible to accurately differentiate the numbers of marine mammals that may be exposed in waters of the global commons (high seas), as opposed to within the South African EEZ. Because the specific location of research activities cannot be predetermined, due to the variables described, this assessment conservatively estimates all exposures occur in waters of the global commons (high seas).

Based on the best available population density estimates, 2413 cetacea may potentially be exposed to sound pressure levels ≥160 dB re 1 μPa.rms. Of the total number of cetaceans that are estimated to be exposed, 60 are U.S. ESA-listed as Endangered; 29 fin (< 0.2% of the S. hemisphere population), 1 humpback (<0.004% of the S. hemisphere population), 11 sei (< 0.2% of the population south of 30°S), 1 southern right (< 0.004% of the S. hemisphere population), and 20 sperm (< 0.02% of the S. hemisphere population) whales. For all species' the number of individuals that would be exposed to sounds ≥160 dB re 1 μPa.rms is less than 0.2 % of the given species' population for which regional population density estimates are known.

Table 4.1 Estimated Number of Mysticetes Exposed to ≥160 dB re 1 μPa.rms

		Number of Individuals per km²				
Mysticetes	**ESA**	**Average (best)**	**Minimum**	**Maximum**	**Occ.**	**Requested Take Authorization**
Antarctic Minke Whale (Balaenoptera bonaerensis)		0.00409	0.00269	0.00631	r	14
Blue Whale (Balaenoptera musculus)	E	0.00003	0.00001	0.00004	r	0
Bryde's Whale (Balaenoptera edeni)		0.00026	0.00000	0.00429	c	1
Common Minke Whale (Balaenoptera acutorostrata)		0.03094	0.01995	0.04828	i	103
Fin Whale (Balaenoptera physalus)	E	0.00859	0.00015	0.01496	r	29
Humpback Whale (Megaptera novaeangliae)	E	0.00010	0.00007	0.00011	r	1
Sei Whale (Balaenoptera borealis)	E	0.00310	0.00030	0.00493	r	11

r – Rare; c – Common; i – Indeterminate; Occ. – Occurrence; E – U.S. ESA Listed as Endangered

Table 4.2 Estimated Number of Odontocetes Exposed to ≥160 dB re 1 µPa.rms

		Number of Individuals per km²				
Odontocetes	**ESA**	**Average (best)**	**Minimum**	**Maximum**	**Occ.**	**Requested Take Authorization**
Arnoux's Beaked Whale (Berardius arnuxii)		0.0045	0.0001	0.0102	r	15
Cuvier's Beaked Whale (Ziphius cavirostris)		0.0035	0.0006	0.0048	c	12
Dwarf Sperm Whale (Kogia sima)		0.0001	0.0000	0.0001	i	0
Gray's Beaked Whale (Mesoplodon grayi)		0.0033	0.0005	0.0046	r	11
Hector's Beaked Whale (Mesoplodon hectori)		0.0028	0.0003	0.0041	r	9
Pygmy Right Whale (Caperea marginata)		0.0000	0.0000	0.0001	i	0
Pygmy Sperm Whale (Kogia breviceps)		0.0000	0.0000	0.0000	i	0
Southern Bottlenose Whale (Hyperoodon planifrons)		0.0064	0.0001	0.0116	r	21
Southern Right Whale (Eubalaena australis)	E	0.0001	0.0000	0.0001	c	1
Sperm Whale (Physeter macrocephalus)	E	0.0058	0.0009	0.0070	c	20
Strap-toothed Whale (Mesoplodon layardii)		0.0028	0.0005	0.0046	c	9
True's Beaked Whale (Mesoplodon mirus)		0.0029	0.0004	0.0044	c	10
Common Bottlenose Dolphin (Tursiops truncatus)		0.0424	0.0108	0.0979	c	141
Dusky Dolphin (Lagenorhynchus obscurus)		0.0001	0.0000	0.0003	r	0
False Killer Whale (Pseudorca crassidens)		0.0002	0.0001	0.0004	i	1
Fraser's Dolphin (Lagenodelphis hosei)		n.a.	n.a.	n.a.	-	0
Heaviside's Dolphin (Cephalorhynchus heavisidii)		0.0035	0.0009	0.0071	r	0
Hourglass Dolphin (Lagenorhynchus cruciger)		0.0010	0.0000	0.0020	r	3
Indo-pacific Bottlenose Dolphin (Tursiops aduncus)		n.a.	n.a.	n.a.	-	0
Indo-pacific Hump-backed Dolphin (Sousa chinensis)		n.a.	n.a.	n.a.	-	0
Killer Whale (Orcinus orca)		0.0090	0.0032	0.0146	c	30
Long-beaked Common Dolphin (Delphinus capensis)		0.0002	0.0000	0.0006	c	1
Long-finned Pilot Whale (Globicephala melas)		0.0539	0.0013	0.1019	r	180
Pantropical Spotted Dolphin (Stenella attenuata)		0.0060	0.0001	0.0138	i	20
Pygmy Killer Whale (Feresa attenuata)		0.0004	0.0000	0.0009	r	1
Risso's Dolphin (Grampus griseus)		0.0631	0.0433	0.1007	c	210
Rough-toothed Dolphin (Steno bredanensis)		0.0005	0.0000	0.0011	r	2
Short-beaked Common Dolphin (Delphinus delphis)		0.2397	0.1278	0.3760	c	799
Short-finned Pilot Whale (Globicephala macrorhynchus)		0.0258	0.0086	0.0408	r	86
Southern Right Whale Dolphin (Lissodelphis peronii)		0.0086	0.0008	0.0206	c	29
Spinner Dolphin (Stenella longirostris)		0.0049	0.0040	0.0103	c	16
Striped Dolphin (Stenella coeruleoalba)		0.1877	0.0276	0.3066	c	626

r – Rare; c – Common; i – Indeterminate; Occ. – Occurrence; E – U.S. ESA Listed as Endangered; n.a. – Not considered likely to occur in area of research activities

5.0 ANTICIPATED IMPACT ON SPECIES AND STOCKS

Potential adverse effects on marine mammals and the marine environment have been determined relative to the research activities proposed, acoustic sources employed in the research, the geographic region of study, and Federal regulations and Navy directives relative to the proposed action. The potential sources of adverse impact that may result in adverse effects derive from:

- Acoustic energy released into the marine environment through operation of the dual 105 in^3 GI-gun array;
- Acoustic energy released through operation of the MBES, SBP, TRDI OS ADCP, and moored and lowered ADCPs;
- Towing of the GI-gun array through the survey area;
- Potential collision of the vessel with marine fauna;
- Accidental loss of streamers and associated equipment.

5.1 Potential Adverse Effects of Acoustic Energy on the Marine Environment

Acoustic energy released into the marine environment has the potential to alter ecosystem dynamics and stability by affecting marine fauna in a several ways. Exposure to anthropogenic sound sources can result in the development of tolerance to the sound source; masking of the auditory and communication frequencies used by marine mammals; behavioral reactions; temporary or permanent hearing impairment; and non-auditory physiological effects. Detailed descriptions of these effects have been thoroughly discussed in scientific literature (Compton et al. 2008; Finneran et al. 2002; Frankel and Clark 2000; Gailey et al. 2007; Kastak et al. 2005; NRC 2005; Popper and Hastings 2009a; Southall et al. 2007) and are well described in related environmental planning documents (e.g., LGL 2010a; NMFS 2007; NSF 2010). As such, these potential effects will be summarized here and focus given to effects with the most potential for occurring.

The effects of tolerance, masking, behavioral reactions, and hearing impairment can result from interference with the sound frequencies utilized by marine mammals for sustenance, mating, and survival, which are listed in Table 5.0. Of the potential effects, short-term behavioral reactions to the acoustic sources, and perhaps some masking effects, are considered possible outcomes of the proposed action.

Table 5.0 Marine Fauna Auditory and Communication Frequencies

	Auditory Range	Vocalization Range
Low frequency cetaceans (Mysticetes)	7 Hz to 30 kHz	10 Hz to 31 kHz
Mid/High frequency cetaceans (Odontocetes)	150 Hz-160 kHz	1 kHz to 150 kHz
High-frequency cetaceans (Odontocetes)	200 Hz to 180 kHz	1 kHz to 150 kHz
Pinnipeds in water	75 Hz to 75 kHz	110 kHz to 170 kHz
Pinnipeds in air	75 Hz to 30 kHz	-
Fish species and elasmobranchs	10 Hz to 1 kHz	100 Hz to 1 kHz

Masking

Masking is the interfering of sounds and frequencies used by marine mammals in foraging, mating, echolocating, and other behaviors intrinsic to health and survival. Acoustic energy released into the marine environment from the proposed research activities may interfere with the ability of marine mammals to effectively communicate and echolocate if anthropogenic sounds obscure those sounds and frequencies used by marine mammals for foraging, communicating, and other actions intrinsic to normal behaviors. Where no overlap of the introduced sound frequencies employed during the research activities with the frequencies used by marine fauna occurs, masking effects are not expected.

Behavioral Reactions

The release of acoustic energy into the marine environment may disrupt behaviors intrinsic to the well being of individual marine animals and sustaining of normal population structures and distributions. Marine fauna may react to the sounds produced during research activities by changing their behavior to avoid the area ensonified by the acoustic sources, which may result in temporary or permanent dislocation of marine mammals from preferred habitats. Behavioral disturbance includes altered foraging practices, dive patterns, communication, migration, and mating. Behavioral reactions are not considered significant to individuals and populations if the reaction is temporary and of no biological significance. However, if the sound generated displaces marine mammals from normal habitat, such as feeding or breeding grounds, for prolonged periods, adverse impacts on individuals and populations could be biologically significant. Such behavioral disturbance depends on the intensity, duration (e.g., acute, chronic), frequency (sound), and periodicity of exposure to acoustic sources, and whether the disturbance is considered to result in a biologically significant, or temporarily insignificant, effect on marine mammal behaviors and habitats.

Tolerance

Prolonged/chronic exposure to sounds that overlap the auditory and communication frequencies natural to marine fauna could result in habituation of individuals to the anthropogenic sound source, and may alter their normal ways of listening and communicating. Due to the relatively short duration of the research project (14 days of SO profiling), movement of the research vessel over a broad area, motility of free ranging marine fauna in the water column and their ability to evade sounds they may prefer to avoid, no tolerance related effects are expected to result from the proposed research activities. It follows, further detailed analysis of the potential for the development of tolerance by marine fauna is not deemed relevant to assessment of the potential adverse impacts of the SO survey.

Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS)

TTS occurs when exposure to a sound more intense than normally experienced results in elevation of the auditory threshold, requiring sounds to be more intense (than normal) in order to be heard. Mammalian studies have determined that TTS can last from minutes to hours, or for days. Most frequently TTS is transient and hearing sensitivity in both terrestrial and marine mammals recovers fairly rapidly on termination of exposure to the sound (Mooney et al. 2009; Tyack 2009; Wartzok 2009). Based on reviews of current studies and data TTS is thought to occur at or above the threshold criteria for Level B harassment (Southall et al. 2007). For odontocetes, mild TTS is considered to be of potential occurrence at received a received level of ~200 dB re 1 μPa.rms from exposure to a single air-gun pulse. Exposure to multiple air-gun pulses at received levels of ~190 dB re 1 μPa.rms is considered the SPL that may result in mild TTS in smaller odontocetes. For mysticetes, there is limited data on TTS; however, it is assumed that TTS thresholds for odontocetes are a close approximations for mysticetes (dependent on sound frequency). As for pinnipeds, TTS is considered to occur at a somewhat higher received level than for small odontocetes exposed for similar durations. However, the threshold for onset of mild TTS in harbor seals, one of the more the sensitive pinniped species, in response to impulsive sounds, has been estimated to be a SEL of ~171 dB re 1 μPa^2.s, or SPL of ~180 to 186 dB re 1 μPa.rms.

PTS occurs when there is physiological damage (barotrauma) to the auditory apparatus of the individual animal, which results in permanent alteration of hearing for the remainder of the individual's life. The duration, peak pressure, rise time, number of pulses, and pulse interval are determinant factors for the risk of PTS in response to impulsive sounds. PTS cannot be systematically studied in marine mammals for obvious ethical reasons and no quantitative information exists, however, based on TTS thresholds and information from the occurrence of PTS in humans and terrestrial mammals, a conservative assumption is that the PTS threshold for marine mammals is at least 6 dB higher than the TTS threshold on a peak-pressure basis. On an SEL basis, it is estimated that received levels would need to exceed the TTS threshold by at least 10 to15 dB for there to be risk of PTS. For cetaceans, it is estimated that the PTS threshold may be a SEL of ~198 dB re 1 μPa^2.s. Regardless of the SEL, there is the possibility of PTS if a cetacean or pinniped receives one or more pulses with peak pressure exceeding 218 dB re 1 μPa (peak) (Southall et al. 2007).

Based on extant data summarized above, NMFS determined that cetaceans should not be exposed to impulsive sounds at received levels >180 dB re 1 μPa.rms, and that pinnipeds should not be exposed to >190 dB re 1 μPa.rms. These threshold criteria are not considered received sound levels at which TTS might occur, they were established as precautionary levels at which it is considered no injurious effects to marine mammals will occur.

Non-Auditory Physiological Effects

Intense acoustic pressures could potentially result in injury and mortality in marine mammals via (1) acoustic excitation of gas/air filled spaces in the tissues of marine fauna, (2) stress related effects, and (3) physical injury other than auditory (e.g., via mechanically induced injury or mortality or indirect effects resulting from altered dive patterns).

Currently, acoustically-mediated bubble growth is considered an unlikely outcome in regard to exposure to a broadband impulsive source such as a GI-gun array (Fernandez et al. 2005; Potter 2004; Southall et al. 2007). One reason is that if bubble formation were to occur, tissue displacement (dependent on bubble size) would likely be too small to result in tissue damage and injury. Another consideration is that resonance and expansion of gas spaces and fatty deposits is not instantaneous; it takes time (at least minutes) to develop (NMFS 2002).

Indirectly, the formation of gas emboli may occur via disruption of normal dive and ascent patterns of deep diving cetacea (e.g., as a result of sonar or GI-guns) resulting in a form of decompression sickness (DCS), as can occur in Scuba divers. Hence, exposure to intense sound sources may result in modification of marine mammal dive and ascent behaviors causing nitrogen supersaturation above a threshold that is normally physiologically tolerated. While there is some evidence for the possibility of the development of a DCS-like condition in marine mammals (Crum et al. 2005; Crum and Mao

1996; Fernandez et al. 2005; Jepson et al. 2003; Jepson et al. 2005), there has been little systematic investigation of this hypothesis, or occurrence of DCS-like responses.

While acoustically mediated physiological injury by way of emboli, tissue swelling, and a DCS-like condition are not to be ruled out, it is also considered, based on extant data, very unlikely to occur in response to the acoustic sources used in the proposed research activities. In general, there is little evidence of these types of effects resulting from the use of low-energy GI-gun arrays during seismic surveys, under the conditions of use described herein.

The induction of stress in marine fauna and resulting alteration of normal physiological indices and functions, such as hormones, blood pressure, and energy expenditure, are also possible effects that may be considered adverse. Concerns regarding stress derive from what is known about the effects of stress in terrestrial mammals. However, little information is available on sound induced stress in marine mammals, and the potential associated affects on an individual's well-being, or effects of populations. Of controlled studies, Romano et al. (2004) describe altered neurological and endocrine system indices in cetacea (bottlenose dolphin and white whale) exposed to impulsive and non-impulsive sounds sources (e.g., 201 dB re μPa), and findings from work by St. Aubin et al. (2002) demonstrate changes in catecholamine and adrenocorticotropic hormone (ACTH) levels in pantropical spotted dolphins pursued by a fishing vessel. An additional controlled study with beluga whales found no stress related response to playback of recorded sounds from an oil drilling platform (Thomas et al. 1990). The findings presented by St. Aubin et al. (2002) describe moderately elevated levels of enzymes indicative of muscle damage and metabolic acidosis in a delphinid species as a result of physiological exertion. However, these physiological metrics describe normal changes that occur in most mammals, to include humans, in response to moderate to intense physical exertion (which returns to normal within hours to a few days), and the significance of these physiological changes in regard to the health and well-being of an individual marine mammal, as well population structure, has not been studied. In each of these investigations, the limited number of animals studied and use of captive animals by Romano et al. (2004) and Thomas et al. (1990), as well as methodological limitations, preclude meaningful extrapolation of the findings to marine mammals in the natural environment.

Stress in humans and other terrestrial mammals generally manifests as a biologically significant effect under conditions of chronic exposure to stressful conditions. Acute responses related to stress are considered largely adaptive in humans and other terrestrial mammals, are typically transient, reparable, and of no long term physiological significance. Acute stress is usually of potential adverse effect only when the opportunity for recovery is significantly hindered. Biologically significant stress related effects, if they occur, would likely be limited to exposures to sound within very close proximity to the acoustic source, and to exposures that occurred over an extended period time (e.g., at least minutes). Given the nature of the research activities, and sound sources employed, chronic exposure of marine mammals to intense sound is considered of very low probability, and biologically significant stress related effects in marine mammals would not be expected to result from conduct of the proposed research activities.

5.2 Potential Adverse Effects of the MBES, SBP and ADCPs

As presented in Table 1.1, the Kongsberg EM 122 MBES generates short acoustic pulses for 2 to 100 ms every 1.5 to 20 s, depending on water depth. Acoustic output frequency is 12 kHz and the maximum source level is 242 dB re 1 µPa.m. The Knudsen 320B/R SBP generates short acoustic pulses of 0.8 to 24 ms at 0.5 to 8 s intervals. Pulse frequency is 3.5 kHz and the maximum source level is 211 dB re 1 µPa.m. The TRDI Ocean Surveyor ADCP will operate at 38 kHz with sound output pressure level of 224 dB re 1 µP.m, producing a ping every 0.2 to 6 s. L-ADCPs will operate at 300 kHz with an output pressure level of 216 dB re 1 µP.m. Moored long-range ADCPs will operate at 75 kHz with an output pressure level of 200 dB re 1 µP.m and pulse interval of 2 s.

The MBES, SBP, and TRDI OS ADCP will be operated from the RV *Melville* during the planned study to verify seafloor conditions and collect additional seafloor bathymetric data. The MBES and SBP will operate continuously, and concurrent, with airgun operations. The TRDI OS ADCP will be operated intermittently to map the distribution of water currents and suspended materials in the water column, and will also be operated concurrent with the dual GI-gun array. The moored ADCPs will operate continuously for approximately 14 days, and L-ADCPs deployed intermittently, to collect hydrographic data.

For any risk of TTS individuals would need be within 100 m of the hull mounted MBES (highest acoustic pressure) to experience a received level of ~185 dB re 1 µPa2.s. If exposed to the MBES or SBP, animals would unlikely be ensonified for more than a single pulse of >10 ms, given the narrowness of the acoustic beamwidths of all instruments, and mobile nature of the vessel and free-ranging marine mammals. Kremser et al. (2005) concluded that an animal would have to pass through the area ensonified by an MBES/SBP transducer at close range, and be moving at a speed and bearing similar to that of the vessel to be subjected to the multiple pulses and sound levels sufficient to cause harm. Similarly, Burkhardt et al. (2007) suggest that auditory injury is possible only if a cetacean dove into the immediate vicinity of a transducer. Other analyses have concluded that standard echosounding instruments, such as the MBES and SBP, are considered to present a low risk of auditory injury, given an individual would have to be within the acoustic beam field, ~10 m or less from the transducer, and receive exposure to 250 to 1000 acoustic pulses to be at risk for a temporary threshold shift (TTS) (Boebel et al. 2004). Based in part on the foregoing discussion, NMFS has determined that brief exposure of marine mammals to a single pulse, or small numbers of pulses from an MBES or SBP, is not likely to result in the harassment of marine mammals (NMFS 2010a, b, 2011b).

The shipboard TRDI OS ADCP operates at similar frequencies and duty cycles, and generates a relatively narrow beamwidth, as do the MBES and SBP, and the TRDI OS ADCP is not expected to pose any significant risk to marine fauna for the same reasons we expect the MBES and SBP to present a low risk of harassment.

In summary, due to (a) the narrow and directional acoustic beam fields of these instruments; (b) the relatively high frequencies of the MBES, SBP and TRDI OS ADCP; (c) that both free-ranging marine animals and the vessel are in motion; and (d) that an animal's bearing and speed would need to parallel that of the vessel to receive exposure to sound pressure for any significant period of time;

harassment of marine mammals as determined under the U.S. MMPA due to operation of these instruments is considered to be of low probability. Hearing impairment and other physiological effects are considered to be of very low likelihood in occurring.

The moored and lowered ADCPs source frequencies of 75 kHz and 300 kHz, respectively, are not expected to pose any significant risk to marine mammals. Neither of the ADCP output frequencies overlap the predominant communication frequencies employed by mysticetes (upper hearing threshold of mysticetes is ~ 30 kHz), which would preclude any significant masking in these species. The lowered ADCP generates sound at 300 kHz, which is inaudible to marine mammals and fish (indirect effects on food sources), and as such, is not expected to pose any auditory or communicative interference. The moored LR-ADCPS will be operated at a depth of ~ 500 m (1640 feet), which exceeds the average diving depths of the majority of cetacea in the research area, particularly species within the delphinidae sub-order (most cetacea dwell in the upper 100 m of water). Of the deep diving cetacea, beaked whales (recorded at depths of 2000 m) have peak auditory sensitivity between 5 kHz and 80 kHz. Hence, the 75 kHz tone generated by the moored ADCPs is at the upper limit of the beaked whales hearing threshold, and not expected to pose a significant risk in terms of TTS, PTS, or result in significant adverse behavioral responses. The sperm whale (recorded at depths of 3000 m) generates clicks in the 2 to 4 kHz and 10 to16 kHz frequency ranges. No direct testing of hearing has been performed on sperm whales, although it is assumed sperm whales hear at the same frequencies at which they vocalize. As such, significant exposure of sperm whales to the moored ADCP sound sources would not be expected to occur. Sound generated by the LR-ADCPs is above the auditory threshold of humpback and southern right whales, and no significant to either species would be expected to occur. The fin whale has a known maximum dive depth of 500 m, although the mean depth of dives is substantially less (e.g., < 300 m). Given these factors, the fairly rapid attenuation of high frequency sound in seawater and the motility of free-ranging marine mammals in the water column, significant exposure of marine mammals to the moored and lowered ADCPs is expected to be of low probability.

Considering the foregoing factors discussed; the potential for the adverse effects of masking, tolerance, TTS/ PTS, and non-auditory physiological injury as a result of operation of the MBES, SBP, TRDI OS ADCP, or moored or lowered ADCPs is considered to be very low. Marine mammal communication and hearing is not expected to be significantly masked by these instruments, given the relatively low duty cycles and brief period of exposure an individual marine mammal may receive if transiting an acoustic beam field. Any behavioral reactions that result from exposure to these sources are anticipated to be short-term, and limited to avoidance of the sound source.

Based on this assessment, previously conducted oceanographic research using same or like kind instrumentation and procedures and environmental studies associated with these previous actions (e.g., NMFS 2004, 2010a, b), and current literature (Boebel et al. 2004; Breitzke and Bohlen 2010; Costa et al. 2003; Kastak et al. 2005; Popper 2008; Popper and Hastings 2009a; Richardson et al. 1995; Tyack 2008, 2009), operation of the MBES, SBP, TRDI OS ADCP and deployed ADCPs is not expected to result in any significant adverse impact on marine mammals, their habitats, or food sources. Of the potential adverse effects, short-term behavioral responses primarily in the way of avoidance of the vessel and lowered and moored ADCPs is considered the only type of effect that will likely occur as a result of operation of these acoustic sources.

5.3 Potential Adverse Effects of the Dual 105 in^3 GI-gun Array

The GI-guns generate dominant frequencies between 10 Hz and 188 Hz, which overlap the auditory and communication frequency ranges used by low and mid frequency cetaceans and pinnipeds. Pinnipeds are likely to be absent in the areas where SO profiling activities will occur, as research activities take place beyond the normal range of Cape fur seals, the only pinniped known to South Africa. This particular species has been recorded up to 220 km (119 Nm) off the South African shoreline, though their normal range is ~160 km (86 Nm) out to sea from shore. Their primary habitat is among the bays of the South African coastline. The SO survey will be conducted in the region of the Agulhas Plateau (>150 Nm from the coast) far removed from primary Cape fur seal habitat. As such, the proposed activities are not expected to pose any significant risk to Cape fur Seals, and the probability of harassment of this species in the area of research is considered very low. Any encounter with Cape fur seals will occur while the RV *Melville* is in transit from port to the site of study, and on return. The only sounds generated during nearshore transits will derive from the vessel proper, as no SO studies will be conducted in pinniped habitat. Given this fact, and prior analyses, it is determined that vessel transit will not pose a significant source of harassment as defined under the U.S. MMPA and U.S. ESA. Subsequent discussion of the potential adverse impacts of the proposed action on marine mammals will exclude consideration of Cape fur seal harassment, as further detailed analysis is not considered relevant to assessment of potential adverse effects that may result from the proposed action.

5.3.1 Masking

Considering the frequencies and output pressure of the low-energy GI-gun array in regard to the total ensonified area and marine mammal population density estimates, the potential exists for possible masking of marine mammal communications and hearing during the SO profiling studies. Effects would be expected to be limited to low- and mid-frequency cetaceans, and any masking effects that occur are expected to be limited to the pulse duration (e.g., ~10 ms), periodicity of the GI-gun pulses (e.g., every 15 to 20 seconds), and transit time of the GI-gun array in a given area. These characteristics of the GI-gun source are considered to permit marine mammals the opportunity to transmit and receive sounds during the intervals between sound pulses. This, in tandem with the fact that free-ranging marine mammals will likely avoid sounds perceived as disruptive, masking effects are anticipated to be minimal and not of a significant nature. Hence, while some masking effects are possible; given the transient ensonification of a given area, the pulse duration, and duty cycle, significant alteration of marine mammal communications is considered to be of low probability, and adverse impacts on population structures and communities is not expected to be a likely outcome of the proposed action.

5.3.2 Temporary and Permanent Threshold Shifts in Hearing

Although the possibility of TTS and PTS cannot be excluded, these types of effects are considered improbable outcomes of the SO survey; given the slow speed of the vessel during the SO profiling studies (e.g., 4 kts); motility of free-ranging marine mammals in water column; and propensity for marine mammals to avoid sounds found obtrusive. For TTS to be of potential risk an individual would need to be within at least ~70 m of the GI-gun array. Given the avoidance of disruptive sounds exhibited by many marine mammals at sound pressures <160 dB re 1 μPa.rms (Southall et al. 2007) it is considered unlikely an individual animal would occur within the 70 m radius for which the risk of TTS is proposed. For the same reasons TTS is considered of low probability, PTS is not considered an effect that is likely to result from operation of the low energy GI-guns. Marine Mammals would need to be within very close proximity to the GI-gun array (e.g., ~20 m) for PTS to occur, and likely for more than a single instantaneous exposure to received levels exceeding 200 dB re 1 μPa.rms. Given the proposed acoustic propagation radii are considered conservative, in conjunction with the monitoring and mitigation measures proposed, TTS and PTS are considered unlikely outcomes of the proposed research activities, and no significant risk of TTS/PTS to marine mammals is considered to be posed.

5.3.3 Non-Auditory Physiological Effects

Non-auditory physiological effects of emboli development, tissue swelling, or a DCS-like condition, as discussed previously, are not expected to occur in any marine mammal. As with TTS/PTS, animals would need to be in very close proximity the GI-gun source (e.g., several meters) for such adverse types of effects to potentially occur, and undergo prolonged exposure (e.g., at least minutes) to intense levels of acoustic energy. Given the slow movement of the vessel, and motility of free ranging marine mammals in the water column, in conjunction with the monitoring and mitigation measures in place, the non-auditory physiological effects described are considered to be of very low likelihood.

5.3.4 Behavioral Reactions

Marine mammal behavioral reactions, in the way of avoidance of the GI-gun array and vessel, are considered a probable response to the proposed research activities. Any behavioral responses to GI-gun sounds that do occur are not expected to be such that any adverse effects on the well-being of individual marine mammals or their populations are expected to result. If marine mammals respond to GI-gun sounds by avoiding the sound and are displace a small distance for a short period of time, this type of response is not considered to result in any significant adverse effect the individual or population structures.

Marine mammal reactions to sound depend on multiple variables, to include species, maturity and experience, activity, reproductive state, the physical oceanographic and bathymetric characteristics that determine acoustic propagation, time of day, health of the individual, and other environmental factors. While information from controlled and in situ studies exists for gray, humpback, bowhead, and sperm whales exists, in general there is limited information on mysticetes, and for most species of odontocetes. Behavioral reactions in the way of avoidance of the GI-gun array and vessel are considered a probable response to proposed activities, although these responses are likely to vary dependent on species.

As reviewed in section 4.0, mysticetes in general tend to avoid air-gun sources, though responses are varied and appear dependent upon species, location, and given species activity during the time at which the seismic survey was being conducted (Arnold 1996; Costa et al. 2003; Croll et al. 2001; Frankel 2005; Frankel and Clark 1998; McCauley et al. 2000; McCauley et al. 1998; Moulton et al.

2006; Moulton and Miller 2005; NRC 2005; Richardson et al. 1999; Southall et al. 2007; Stone and Tasker 2006; Wartzok 2009; Williams et al. 2002). A substantial portion of the populations of gray, humpback, and bowhead whales exhibited avoidance to air-gun sounds at received levels of ~160 to170 dB re 1 μPa.rms, and localized displacement of humpback whales during migration (~4 km by traveling pods and 7 to12 km by pods of cow-calf pairs) was observed in response air-gun sounds at received levels of ~140 dB re 1 μPa.rms (R.D. McCauley et al. 2000; McCauley et al. 1998). Observations for bowhead whales also suggest foraging, as well migratory conditions, may determine the degree of behavioral response (Miller et al. 1999; Richardson et al. 1999). For instance, bowhead whales have been observed to exhibit a lesser response to air-gun sounds while engaged in foraging (Harris et al. 2007; Miller et al. 2005), typically avoiding sound only when received levels approached 150 to178 dB re 1 μPa.rms. Similarly, studies on gray whales during foraging suggest that only around half the whales stopped feeding (in response to air-gun sounds) at received levels of to178 dB re 1 μPa.rms. Observations are quite limited, but suggest mysticete behavioral responses are relative according to foraging and migratory activities, as well as sex and calving status. The majority of observations and studies suggest that odontocetes in general exhibit a tendency to avoid vessels involved in seismic surveys, though to a lesser degree as compared to mysticetes. Most observations to date suggest the avoidance distance for smaller odontocetes and delphinids is significantly less than that for mysticetes and larger toothed whales.

5.3.5 Potential Non-Acoustic Related Effects

Other potential adverse effects are those of direct physical disturbance of the marine environment as a result of instruments lowered into the water column (VMP, L-ADCP), moored on the ocean floor, possible collision of the towed GI-gun array or vessel with marine fauna, disposal of expandable XBTs/XCTDs, and accidental loss of streamers and associated equipment. Deployment of XBTs in the marine environment is not expected to result in any adverse impact on the marine environment. Similarly, deployment of the L-ADCP rosettes and lowering of the VMP into the water column are not expected to result in any adverse impact on the marine fauna, their habitats, or food sources. On recovery of the moored ADCPs the iron anchors (locomotive wheels) will be left on the seafloor at the end of the third leg. Presence of the iron locomotive wheels anchors on the seafloor is not considered to pose any significant risk. Due to concretion and the degradation rate of iron in seawater, which can be on the scale of decades, and the fact that locomotive wheels pose no risk of toxicity, the presence of the iron on the seafloor is not considered to result in any potential adverse impacts on marine fauna or their habitats.

While the potential for the loss of streamers and associated equipment exists, which may pose risks to marine fauna via potential entanglement in the streamers, the probability of this occurring is considered very low. We do not anticipate this event occurring nor the resulting adverse impacts that may result.

Entanglement of marine fauna in the air-gun array and vessel strike during the SO survey is possible, however, these have been historically somewhat rare events as related to research vessels conducting seismic surveys. Jensen and Silber (2004) found that in 89 % of collision accounts that resulted in fatalities or injury, vessels were moving at 14 kts or faster, and no collisions have been reported at speeds of less than 10 kts (e.g., the SO survey will be conducted at 4 to 6 kts). The RV *Melville* has a cruising speed of 11.7 knots, and maximum speed of 14 knots: Considering the slow speed of the RV *Melville* while conducting SO surveys, and implementation of the planned monitoring and mitigation measures, entanglement and/or vessel strike is considered to be of very low probability.

LR-ADCPs will be moored to the seafloor at a ~3000 m such that they float at a depth of 500 meters below the sea surface. ADCPs, anchored to the sea-floor by scrap iron locomotive wheels, are suspended by a single suspension line comprised of ¾" inch nylon and ½" wire rope, which is held taught by a suspension buoy. The taught suspension and relative thinness of the mooring lines, and the large distance between the two moorings (>1 km), renders entanglement unlikely. There are no known reports of marine fauna entanglement in the suspension line of ADCPs moored as described.

5.3.6 Summary of Potential Adverse Impacts on Marine Mammals

The proposed research activities entail the use of a low-energy dual 105 in^3 GI-gun array, MBES, SBP, TRDI OS ADCP, and lowered and moored ADCPs, which will introduce acoustic energy into the marine environment. From the foregoing analysis, it is determined that low- and mid-frequency mysticetes and odontocetes may respond to sounds generated by the GI-gun array. However, the responses are expected to be limited to avoidance of the GI-gun sound source as the vessel transits ~2489 km over the area proposed for SO profiling studies. Routine vessel operations are not assumed to affect marine mammals sufficiently to constitute harassment, and no taking of marine mammals is expected in association with operation of the MBES, SBP, TRDI OS ADCP, and lowered and moored ADCPs.

6.0 ANTICIPATED IMPACT ON HABITAT

6.1 Potential Adverse Effects on Marine Mammals

Operation of the MBES, SBP, ADCPs, and GI-gun array is not expected to result in any significant impact on habitats used by marine mammals in the proposed survey area. While it is anticipated that the proposed action may result in marine mammals avoiding certain areas due to temporary ensonification of the water column, this type of impact on habitat is considered to be highly transient and not an effect with any significant adverse outcomes in terms of habitat modification.

Regarding the potential for indirect effects on habitat via disruption of food sources; these are expected to be limited to the potential for morbidity or mortality to small fish, their eggs, larvae, and invertebrates. However, any disturbance to fishes or invertebrates is expected to be short-term. Those species affected by the sound sources are assumed to resume normal behavior once the vessel passes a given area. It follows; the proposed SO survey is not expected to have any significant direct or indirect impact on marine mammal habitat via disruption of food webs. A review of the potential impacts on fishes and invertebrates follows.

6.2 Potential Adverse Effects on Fishes

The potential adverse effects of the GI-gun sound source on fishes (including elasmobranchs) include physiological injury and mortality, behavioral avoidance of ensonified areas resulting in distributional variations, masking of auditory and communication frequencies and sounds, and indirect impacts due to adverse effects on food sources.

The majority of fishes sense the intensity and direction of sound pressure, and many species, not surprisingly, exhibit varying degrees of startle and alarm responses, such as a C-start response, to intense sounds. Most fish species can hear sounds from a few Hz up to ~1 kHz. As with marine mammals, fish exposed to intense sound pressures can develop TTS, and suffer PTS (Popper and Hastings 2009a). The effects of TTS/PTS however have been limited to exposures to within a few meters of an air-gun source, and source of significant acoustic energy. Aside from auditory effects, fish have also been observed to exhibit a stress response via elevated stress hormones and associated biomarkers of stress in response to intense sound (Santulli et al. 1999).

With fishes, due to rates of reproduction and population sizes of many species, the potential adverse effects of concern are more associated with their population structures and ecosystem dynamics, as opposed to individuals. In part, this renders estimating the potential impacts of acoustic energy released into the environment somewhat problematic given it is difficult to assess, due to the lack of studies and information currently available on population dynamics, the affect GI-gun sounds have on fish populations and distribution. In general, data are mixed on the displacement of fish during operation of GI-guns (Popper et al. 2007; Popper and Hastings 2009b; Popper et al. 2005). Where avoidance of areas during seismic surveying has been associated with reduced catch in some species, in other species, only localized displacement of fishes (e.g., downward movement of fish in the water column to avoid the sound) has been observed.

In terms of primary effects there are several reports describing injury and mortality to fish eggs and larvae on exposure to seismic source sound pressures. In general, these types of injurious/lethal effects occurred in close proximity to seismic sources, typically within 5 to 15 m of the sound source, and at significant pressures in the range of received sound pressure levels of ~215 to 233 dB re 1 μPa (0-p).

From the foregoing analysis it is determined that during the SO studies a relatively small fraction of fish habitat would be ensonified at any given point in time. Any disturbance to fishes would likely be short-term, and fishes are expected to assume normal behavior once the research vessel has traversed a given area. While the potential for the adverse effects of masking, disturbance, tolerance, TTS and PTS, and non-auditory injury exist, behavioral effects such as avoidance are the only adverse effects that are considered probable outcomes of the proposed activities.

The potential for collision of the towed GI-gun array or vessel with fishes, while not to be ruled out, is considered to be of very low probability. Given the acoustic sources are mobile, and that free-ranging fishes in the water column are highly motile, the probability that any animal would remain within an ensonified area for any extended period of time is considered very low. The SO profiling activities will be conducted for two weeks, over a large area far removed from primary fishing grounds (majority of which are within 200 km of the coast), and any adverse behavioral effects are expected to be temporary. Hence, short-term behavioral effects potentially resulting in localized displacement of fishes is not considered likely to significantly affect population structures, ecosystem dynamics, or marine mammal food sources. Where disturbance to fish population structures and distributions could potentially result in the temporary displacement of fish from normal habitat and fishing grounds, this effect would be of such a transient nature that no significant near term or long term adverse impacts to fishes, their populations, or habitats.

6.3 Subsistence Harvesting of Marine Mammals

Subsistence fishers are found on the Pondoland (Transkei) coast and the northern coast of Kwazulu Natal, South Africa, and formally recognized as a unique fisheries sector in 1998 by the South African Marine Living Resource Act (MLRA). Approximately 28,000 people are identified as subsistence fishers and there are ~175,000 people directly dependent on marine resources to meet the basic requirements for living. Virtually all subsistence fisheries are located within the EEZ, most within 100 Nm of the coast. Because there are no known subsistence fishers that utilize marine mammals as a natural resource, no impacts to subsistence uses of marine mammals would be expected to occur.

6.4 Potential Adverse Effects on Marine Invertebrates

Information on the effects of underwater sound on marine invertebrates is limited to a few select species. Many invertebrates are known to have some sense of perception of acoustic energy, among them, crustaceans (e.g., crabs, lobsters, shrimp, prawns) and mollusks (e.g., cephalopods - octopus, squid, cuttlefish) are known to sense low-frequency sound. Cephalopods have more sophisticated hearing, as well as vision, chemoreception, and proprioception.

Both crustaceans and cephalopods appear to be sensitive to sound pressure at frequencies below 1 kHz. Of the limited studies that have been conducted, findings suggest little behavioral or physiological response of crustaceans to rather intense sound pressures. No adverse long term effects have been observed in snow crab or lobster exposed to significant sound pressure for extended periods of time (e.g., a minimum of 20 to 200 pulses at SPLs of 191 to 221 dB re 1 μPa (0-p) and SELs of 130 to 187 dB re 26 1 μPa^2.s.) (DFOC 2004; Payne et al. 2007; Christian et al. 2003; Christian et al. 2004). A study by Parry and Gason (2006) found no effect of seismic surveys (large 12 to 32 gun arrays) on the catch of rock lobster in Australia.

As with crustaceans, there are few controlled studies on cephalopods, however, some species appear more responsive than do crustaceans. At SPLs >200 dB re 1 μPa(0-p) squid exhibited behavioral and startle responses such as avoidance of the sound source, surfacing, and firing of the ink sac (R.D. McCauley et al. 2000). Similarly juvenile cuttlefish (*Sepia officinalis*) exhibited various behavioral responses to frequencies between 0.01 and 1 kHz (Komak et al. 2005). In general, data on which to assess the potential adverse effects of GI-gun sounds on invertebrate species is rather ambiguous, however, of the limited data available, crustaceans and cephalopods appear sensitive and responsive to the frequencies of sound generated by air-guns, although at sound pressures somewhat higher than that for marine mammals.

Assessment of the effects of acoustic energy on marine invertebrates is to some degree conjectural, based on the auditory apparatus and mechanism by which invertebrates perceive sound. Marine invertebrates are known, not surprisingly, to use sound for mating, and for marine invertebrates that produce sounds (e.g., shrimp, lobsters) it is considered a mechanism for survival against predators. Several species are known to have statocysts, auditory structures similar to the ears of fishes, which are considered to serve for detection of low-frequency sounds. While there are no data for marine crab hearing a number of species of semi-terrestrial fiddler and ghost crabs are known to detect and use sounds for communication, and physiological studies of the statocysts of marine crabs suggest that many species are potentially capable of sound detection (Popper et al. 2001).

The potential for significant adverse impacts on crustacean and cephalopods, as well as sponges and corals, is expected to be limited to the GI-gun sound source, and any potential adverse effects would occur from exposures within very close proximity to the sound source. Given the depths (1000 m to 5200 m) and region of study adverse impacts on crustacea are expected to be minimal. No adverse impacts on benthic crustacean are expected to occur, though exposure of shrimp and related species, as well as cephalopods, are possible.

As with the analysis of potential adverse impacts on marine mammals and fish, it is considered that only a small fraction of available habitat would be ensonified at any given time, and motile invertebrates capable of detecting low-frequency sound are expected to avoid sound pressures found disturbing. Any adverse effects on crustacean and cephalopods are expected to be short-term, with little if any repercussions on their populations or marine food webs.

The impacts of air-guns on phytoplankton and zooplankton, primary producers in the marine food-web, have not been well studied, however, the potential adverse impacts of the GI-gun pulses on plankton would likely be limited to mortality or injury to plankton in the immediate vicinity of the GI-gun array (e.g., <5 m from the GI-guns). In general, any adverse impacts on plankton that may result from use of the low-energy GI-gun array are expected to be insignificant, given their biomass and rates of reproduction.

While short term behavioral responses by some invertebrate species (e.g., cephalopods, decapods), as well as mortality and injury to phyto- and zooplankton, may occur, these are not expected to result in any significant near or long impacts to marine invertebrate populations, pelagic food webs, or the local ecosystem. Vessel collision with cephalopods and related invertebrates is possible, though it is not considered a likely outcome of the proposed action. Benthic invertebrates would not be significantly disturbed given the depths of the region of study. Based on the foregoing analysis and current data, the research activities proposed are not expected to result in any significant adverse effects on invertebrates, or indirect effects on marine mammals via alteration of marine food webs.

6.5 Anticipated Impact on Loss or Modification of Habitat

The proposed SO survey will not result in any permanent loss or modification of habitats used by marine mammals, or to the food sources they use. As described, the primary impact on habitat will be temporary ensonification of the water column and the associated direct and indirect effects on marine mammals. During SO studies, only a small fraction of the available habitat will be ensonified for a short duration of time as the vessel transits a given area. Disturbance to fishes would be short-term and it is expected that responsive fishes would return to their normal behaviors once the vessel has transited a given area. While short term behavioral responses by some invertebrate species (e.g., cephalopods, decapods), as well as mortality and injury to phyto- and zooplankton, may occur, these are not expected to result in any significant near or long impacts to marine invertebrate populations, pelagic food webs, or the local ecosystem. The research activities are expected to have little impact on the abilities of marine mammals to forage in the area where research activities will be conducted, and not expected to result in any significant short- or long-term loss or modification of marine mammal habitat. As discussed previously, the presence of the iron locomotive wheel anchors on the seafloor is not considered to pose any significant risk to loss or modification of marine fauna habitat.

7.0 MITIGATION MEASURES

Monitoring, mitigation, and reporting procedures will be in place to minimize the likelihood of adverse impacts on marine mammals and sea turtles. Marine Mammal Observers (MMOs), bridge personnel, officers, and principle investigators, will follow guidelines established by the United States Navy Integrated Comprehensive Monitoring Program (NAVY 2010), and the U.S. Navy's Marine Species Awareness Training (MSAT). MMOs meet the following minimum requirements: (a) BS degree in Biology, or related major; (b) Training and participation in NOAA/NMFS mammal/bird survey cruise; (c) Experience with survey software; and (d) Subsequent participation in mitigation effort on non-biology-survey cruise(s).

Procedures will include GI-gun ramp-up, shut-down, and power-down, as well as visual monitoring for the presence of marine mammals. However, where power-down is a standard and effective measure, powering down of the GI-gun array in this instance may not prove effective given the use of one versus two GI-guns would result in only a modest difference in the level of acoustic energy output. It follows, mitigation measures will be likely be comprised of ramp-up, shutdown, and course/speed alteration. Proposed exclusion zones and mitigation measures are discussed following.

Proposed Exclusion Zones

Exclusion zones (EZ) will be based on the exposure threshold isopleths applicable to cetaceans and pinnipeds, respectively, as previously discussed. Based on extant models of same/similar GI-gun sources and water depths, the proposed EZs are 20 m, 70 m, 160 m, and 670 m for the 190, 180, 170 and 160 dB re 1 μPa.rms exposure thresholds, respectively. The 160, 180, and 190 dB isopleth EZs will be employed for monitoring, and are considered consistent with NMFS guidelines listed for cetaceans and pinnipeds.

Speed or Course Alteration

If a marine mammal is detected outside the EZ but is considered likely to enter the EZ vessel speed and/or course will be attempted to be adjusted to minimize the likelihood of the animal broaching the EZ. Course and speed alteration are not always possible when towing a long GI-gun array, though are considered possible options in this case given the use of a dual GI-gun array.

Shutdown Procedures

If the vessel's speed and/or course cannot be changed to avoid an animal entering the EZ, shutdown of the GI-gun array will be implemented if a cetacean is observed within or approaching the 180 dB re 1 μPa.rms isopleth (70 m), or if pinnipeds are detected within or about to enter the 190 dB re 1 μPa.rms isopleth (20 m). Airgun activity will not resume until the marine mammal has cleared the EZ, or until a MMO is confident that the animal has left the EZ, or has not been observed within the EZ, for at least 15 minutes for small odontocetes and pinnipeds, and at least 30 minutes for large odontocetes and mysticetes.

Ramp-Up Procedures

Ramp-up will be comprised of gradually activating the dual 105 in^3 GI-guns in sequence over a period of ~30 minutes until the desired operating level is reached, which permits marine fauna in the area to avoid the sound source in a timely manner. Airguns will be added in a sequence such that the source level of the array will increase in steps not exceeding 6 dB per 5-min period over a total duration of ~30 min. During ramp up, MMOs will monitor the EZ for marine mammals and a shutdown will be implemented if an animal is detected. As described, airgun activity will not resume until the marine mammal has cleared the EZ, or until the MMO is confident that the animal has left the EZ.

8.0 MONITORING AND REPORTING

Measures for ramp-up procedures during GI-gun operations will include visual monitoring of waters by MMOs for the presence/absence of marine mammals for at least 30 minutes before initiating ramp-up. Visual monitoring will be comprised of three (3) MMOs. MMOs will work in shifts of 4-hour duration or less. MMOs have undergone NOAA/NMFS training for marine mammal and seabird observation, are experienced with mitigation measures and survey software, and have participated in prior research cruises. The RV *Melville* crew will also be instructed to assist in detecting marine mammals. A MMO platform is located one deck below and forward of the bridge (12.5 meters (~41ft) above the waterline), providing a relatively unobstructed 180 degree view forward. Aft views can be obtained along both the port and starboard decks.

During daytime operations, MMOs will systematically survey the area around the vessel with reticulated 25x150 big eye binoculars and 7x50 hand held binoculars to determine bearing and distance of sitings. A clinometer will be used to determine distances of animals in close proximity to the vessel, and hand-held fixed rangefinders and distance marks on the RV *Melville's* side rails are used to measure the exact location of the EZs. During nighttime operations, night vision devices (NVDs) will be available if required. The observers will be in wireless communication with ship's officers on the bridge and scientists in the vessel's operations laboratory, so they can promptly advise of the need for avoidance maneuvers or seismic source shut down. Shut-down of GI-gun operations will occur immediately upon observation/detection of any marine mammal in the EZ by a MMO. Following a shut down, GI-gun ramp-up will not be initiated until MMOs have confirmed the marine mammal is no longer observed/detected for a period of 15 or 30 minutes, as described above. If a marine mammal is outside of the exclusion zones and observed by a MMO to exhibit abnormal behaviors consistent with signs of harassment (e.g., avoidance, dive patterns, multiple changes in direction), operation of the GI-guns will cease until the animal moves out of the area or is not re-sighted for a period of 30 minutes.

When a marine mammal is detected, the following information will be recorded, if determinable:

- The time, location, heading, speed, activity of the vessel, sea state, visibility, and sun glare.
- Species, group size, age, individual size, sex (if determinable);
- Behavior when first sighted and subsequent behaviors;
- Bearing and distance from the vessel, sighting cue, exhibited reaction to the air-gun sounds or vessel (e.g., none, avoidance, approach, etc…), behavioral pace, and depth at time of detection;
- Recording fin/fluke characteristics and angle of fluke when an animal submerges to determine if the animal executed a deep or surface dive;
- Type and nature of sounds heard;
- Any other relevant information.

Shutdown Reporting: A report documenting the need for a shutdown will be prepared and include the following information:

- The basis for decisions resulting in shut down of the GI-guns;
- Information needed to estimate the number of marine mammals potentially taken by harassment;
- Information on the frequency of occurrence, distribution, and activities of marine mammals in the area of study;
- Information on the behaviors and movements of marine mammals during and without operation of the GI-guns;
- Any adverse effect the shutdown had on the research.

Exposure Reporting: MMOs will provide estimates of the numbers of marine mammals exposed to the GI-gun source and any disturbance reactions exhibited, or the lack thereof. Observations and data collection will aim to provide estimates of the actual numbers of animals taken by harassment (as defined in the U.S. MMPA), verify the level of harassment, aide in assessment of impacts on populations on conclusion of the study, and increase our knowledge of species' in the area of study. Observations and data collection will also aim to provide information that will allow for verifying or disputing that the takings are negligible.

Final Report: On conclusion of the research activities, a final report will be compiled, which will describe the operations conducted, and sightings/detections of marine mammals near the operations. The report will provide documentation of methods, results, and interpretation pertaining to all monitoring, including the dates and locations of the research activities, and all marine mammal sightings (dates, times, locations, behaviors). All reporting requirements will be coordinated with NMFS prior to the commencement of research activities.

9.0 COORDINATION WITH OTHER AGENCIES AND INITIATIVES

NRL, in consultation with the Office of Naval Research (ONR), and the Chief of Naval Operations, Energy and Environmental Readiness Division (N45), will coordinate with NMFS on any IHA or other authorization that may be required to engage in the proposed action, as well as monitoring and mitigation procedures to be implemented. The NRL will also coordinate the planned monitoring and mitigation program described with other parties that may have interest in marine mammal research, and the area of study. As described herein, the research endeavor is a collaborative project between NRL Chief Scientists Dr. Warren Wood and Dr. Jeff Book, Dr. David Vousden, Director of the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project, and Dr. Isabelle Ansorge, of the University of Cape Town, South Africa. There should be ample opportunities for interested students and colleagues of collaborators to participate in the proposed project, and marine mammal-monitoring program.

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